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A Summary of Current Program and
Preliminary Report of Progress

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COTTON AND COTTONSEED RESEARCH

of the

United States Department of Agriculture
and related work of the
State Agricultural Experiment Stations

This progress report is primarily a research tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs. The summaries of research progress include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C. 20250

February 1966

ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources and Facilities Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research
12. Plant Science and Entomology Research
13. Tobacco Research

ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

Agricultural Research Service (ARS)

- 1 - Agricultural Engineering
- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Clothing and Housing
- 3 - Consumer and Food Economics
- 4 - Market Quality
- 4 - Transportation and Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease and Parasite
- 12 - Crops
- 12 - Entomology

Economic Research Service (ERS)

- 1, 5 - Economic Development
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic and Statistical Analysis
- 5 - Foreign Development and Trade
- 5 - Foreign Regional Analysis
- 5 - Natural Resource Economics
- 6 - Forest Service - Research (FS)
- 4, 5 - Farmer Cooperative Service (FCS)
- 4, 5 - Statistical Reporting Service (SRS)

SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the USDA program and progress for the following commodities and subjects:

- 6 - Forestry (other than Forest Service)
- 7 - Beef Cattle, Part I-a
- 7 - Dairy, Part I-b
- 7 - Poultry, Part I-c
- 7 - Sheep and Wool, Part I-d
- 7 - Swine, Part I-e
- 7 - Animal-Poultry and Products, Part II
- 8 - Cotton and Cottonseed
- 9 - Grain and Forage Crops
- 10 - Horticultural Crops
- 11 - Oilseed and Peanut
- 11 - Sugar
- 13 - Tobacco

A copy of any of the reports may be requested from Axel L. Andersen, Executive Secretary, Cotton Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250.

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INTRODUCTION

This report deals with research on cotton and cottonseed. It does not include extensive cross-commodity work, much of which is basic in character, which contributes to the solution of not only cotton and cottonseed problems, but also to the problems of other commodities. Progress on cross-commodity work is found in the organization unit reports of the several divisions.

This report is organized by problem areas which are shown as the major subjects under the three main divisions in the table of contents. For each of the problem areas there is a statement of (1) the Problem, (2) USDA AND COOPERATIVE PROGRAM, (3) PROGRAM OF STATE EXPERIMENT STATIONS, (4) PROGRESS--USDA AND COOPERATIVE PROGRAMS, (5) PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS.

Cotton and cottonseed research is supported by (1) Federal funds appropriated to the research agencies of the U. S. Department of Agriculture, (2) Federal and State funds appropriated to the State Agricultural Experiment Stations, and (3) private funds allotted, largely by cotton and cottonseed industries, to research carried on in private laboratories or to support of State Station or USDA work.

Research by USDA

Farm research in the Agricultural Research Service dealing with cotton and cottonseed comprises investigations on breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, harvesting, handling operations and equipment, and cotton ginning. This research is conducted by the Crops, Entomology and Agricultural Engineering Research Divisions of the Agricultural Research Service. There were 191.8 professional man years devoted to research in this area.

Nutrition, consumer and industrial use research in the Agricultural Research Service is directed toward improved methods and equipment for milling processes, textile finishing; development of new and improved uses of both cotton and cottonseed, and increasing the consumer acceptance of cotton textiles and of food products containing cottonseed. The work is done by the Southern Utilization Research and Development Division, New Orleans, Louisiana; the Clothing and Textiles Laboratory at Beltsville, Maryland; and under contract with state and foreign country laboratories, and in cooperation with the industry and other organizations mentioned under programs for each research area. The work involved 246.9 professional man years last year.

Marketing and economic research is done in three services. Marketing research in the Agricultural Research Service dealing with cotton and cottonseed is concerned primarily with the physical and biological aspects of assembly, packaging, transporting, storing and distribution from the time the product leaves the farm until it reaches the ultimate consumer. It is carried out by the Market Quality and Transportation and Facilities Research Divisions, and involved 15.3 professional man years in 1965.

Economic research conducted in the Economic Research Service deals with marketing costs, margins, and efficiency; market potentials; market structure, practices, and competition; outlook and situation; and supply, demand, and price. Consumer preference studies are carried out by the Statistical Reporting Service. Research in cooperative marketing is conducted by the Farmers Cooperative Service. The cotton and cottonseed research in these services involved 16.9 professional man years of scientific effort.

Interrelationships among Department, State and Private Research

A large part of the Department's research is cooperative with State Experiment Stations. Many Department employees are located at State Stations and use laboratory and office space close to or furnished by the station. Cooperative work is jointly planned, frequently with the representatives of the producers or industry affected participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators which frequently includes resources contributed by the interested producers or industry.

USDA cooperative and State Station research projects on cotton and cottonseed is in progress in 18 of the 53 State Agricultural Experiment Stations. The types of work to which the largest amount of effort is devoted include cotton culture, breeding, diseases and variety evaluation.

Industry's participation in cotton and cottonseed research is sponsored largely by commercial seed breeders, chemical companies, farm equipment manufacturers, cotton textile manufacturers, textile schools, manufacturers of finishing agents, textile finishers, textile research institutes, textile chemical manufacturers, processors, department stores, mail order houses and manufacturers, and cotton producers.

Example of Recent Research Accomplishments by USDA and Cooperating Agencies

Automation of Fiber and Spinning Tests. Progress has been made toward automating fiber testing at the USDA Laboratory, Knoxville, Tennessee. An assembly line has been placed in operation with tests for length (digital fibrograph), fineness (micronaire), color (colorimeter), and a visual measure for trash. Data are automatically recorded on punch cards, processed through a computer, and print-out results sent to the cooperators. Present instruments for measuring strength cannot be run at the same speed as the above-mentioned measurements; however, operations have been set up with the stelometer to record breaks and weights of the broken samples directly on punch cards. Calculations and adjustments to standards are then made by computers and stelometer measurements can be included as print-outs.

Release of Seed Stocks. The New Mexico and Arizona Agricultural Experiment Stations and the U. S. Department of Agriculture jointly released Hopicala, a productive variety with excellent fiber properties. Although this cotton was bred in New Mexico, extensive testing over the Western region indicated that it was well adapted in Arizona. It yields well in New Mexico, but because the fiber length is about 1/16 inch shorter than that of the Acala 1517 types, it is not recommended in the El Paso trade territory. Fiber of Hopicala is as long as varieties currently grown in Arizona. Its higher tensile strength gives it a significant advantage in quality as measured by yarn strength. The development of Hopicala illustrates the advantages of cooperative effort among agencies and the effectiveness of regional testing.

Abscisin II in the Cotton Plant. The chemical structure of the naturally occurring growth substance, abscisin II, has been determined by the USDA - University of California research team and was found to be different chemically from growth regulators previously known. Proof of the structure by chemical synthesis has been announced by a group of British researchers. Abscisin II is identical with a substance regulating bud dormancy which the British researchers had named "Dormin." Chemical synthesis by the USDA - University of California group has yielded an analog differing from abscisin by 2 hydrogen atoms whose biological activity equals abscisin II extracted from the cotton plant. In addition to the regulation of abscisin (defoliation), abscisin II is known to inhibit plant growth, to promote plant aging, and to induce dormancy in buds. Its potential usefulness in crop production and harvesting operations is obvious. Chemical synthesis of sufficient quantities for these investigations are currently underway.

Cotton Ginning. Research has made possible the effective ginning of the machine and rough hand-harvested seed cotton. The developments of this research program have been a primary factor in maintaining the competitive position of cotton.

Light Traps for Insects. Research on light traps for insects has made this device a very effective means for detection and estimation of insect infestation. This development has aided quarantine activities and the planning of chemical control operations. More than 700 electric traps are in use to determine emergence and migration of the pink bollworm moth in the Southwest and the European chafer in the Northeast and thus facilitate more efficient use of chemical controls. An additional 400-500 traps are used for detecting mosquito populations. An estimated 400-500 general purpose electric traps are in use to determine new infestations of economic insect pests. Special multipurpose traps are used at points of entry to detect foreign insects.

Natural sex attractant of pink bollworm employed in regulatory detection program. Methods have been developed for rearing large numbers of pink bollworm moths and for the preparation of extracts from the virgin females that are strong male attractants. Extracts supplied to the Plant Pest Control Division in 1964 and 1965 have been utilized successfully in surveys to detect incipient infestations. Studies to develop methods of utilizing this strong attractant in control are being continued. Chemical investigations have determined the structure of the active component of the attractant and research is underway to synthesize it.

Nuclear polyhedrosis virus promising for control of bollworm-tobacco budworm complex on cotton. Field evaluations of a bollworm polyhedrosis virus at a dosage of 100 diseased larvae per acre provided control as effective as 2 pounds of toxaphene plus 1 pound of DDT at Brownsville, Texas; 2 pounds of carbaryl at Waco, Texas; and 1 pound of DDT at Tallulah, Louisiana. Studies on mammalian toxicology are being continued to develop information which will permit registration of insect viruses for practical use in insect control. Studies on mass production of several insect virus diseases are continuing.

Better performance with improved designs of cottonseed aeration systems. For a number of years, stored cottonseed has been aerated to help maintain its moisture content and temperature at a satisfactory level to minimize seed deterioration. However, due to a lack of reliable engineering data, many present systems are not giving adequate protection to the stored seed. Results of studies underway in the Mississippi Delta show that the use of efficient fans and well designed dust systems greatly improves the performance efficiency of aeration systems. In addition to the improvement in quality maintenance with the improved systems, there is also a substantial saving in power.

Superior Wash-Wear Finishes Adopted by Industry to Enhance the Competitive Position of Cotton. Carbamate wash-wear finishing agents, developed by Department research scientists, are being produced commercially in the U. S. and abroad. These agents are currently used to treat an estimated one million yards of cotton fabric per day. The carbamates produce high-quality wash-wear finishes with outstanding durability to damage by laundering and chlorine bleaching. In addition to retention of smart appearance, the superior durability prevents garment shrinkage after a few launderings as sometimes occurs with cottons treated with less resistant finishes. Research has indicated that superior lightfastness of dyed fabrics can be achieved by the use of carbamate agents with modified alkyl groups. One such agent, dimethylol hydroxyethyl carbamate, shows promise for quick commercialization. In addition to being attractive for manufacturing conventional wash-wear products, this carbamate appears to be a good agent for deferred cure finishing to produce durably creased, wash-wear cotton garments. Moreover, this new agent is readily available and potentially inexpensive. Representatives of three large industrial manufacturers have stated that the cost of carbamate intermediates used in preparation of these wash-wear finishes can be reduced to make the new agents competitive with all but the cheapest wash-wear agents.

Industry Adopts New Zirconium-Copper Treatment to Improve Service Life of Outdoor Cotton Fabrics. In cooperation with the Canvas Products Association International and the Foundation for Cotton Research and Education (affiliated with the National Cotton Council of America) Department scientists recently developed an efficient, inexpensive treatment based on new zirconium-copper antimicrobial agents for improving cotton fabric's resistance to weather and rot. The discovery of a method of solubilizing various inexpensive fungicides (such as copper borate) with zirconyl acetate and zirconyl ammonium carbonate made the new treatment possible. The new agents, all the components of which are commercially available, have the advantages of good resistance to micro-organisms such as mildew and algae, good durability, low cost, no odor, and ease of application. More than thirty companies have expressed interest in the discovery, and five of these are currently using the new treatment for commercial production of outdoor weatherable cotton fabrics. Cotton duck finished with this treatment has completely resisted mildew and algae growth for more than 36 months of outdoor exposure. The QM Research and Engineering Command, U. S. Army, Natick, Mass., has reported that recently completed preliminary tests by an independent testing company indicate that the finish is superior to any other commercially available additive-type fungicide. The major potential for these new antimicrobial agents is for tarpaulins, shoe linings, boat covers, industrial thread, awnings, and tobacco shade cloth. The market potential is estimated to be equivalent to 265,000 bales of cotton per year.

Improved Methods and Organization for Cotton Cooperatives. A series of research projects is nearing completion that point to methods of reducing ginning cost to farmers by \$5 a bale. Value of cotton can also be increased by \$1 to \$5 a bale through scientific blending. The various operating methods studied include choice between single and multiple gins, basket storage of seed cotton, and central ginning. Potential savings to all U.S. cotton farmers from a full re-structuring of cotton ginning methods and organization for this purpose appear to be about \$100 million per year.

Impact of Reduced Prices on Use of Cotton. Special analyses were completed on the impact of reduced cotton prices following new legislation on mill use of raw cotton, imports and exports of cotton textiles, and the use of cotton and manmade fibers. The improved competitive price position of cotton in the domestic market, resulting from enactment of new legislation in 1964, sharply increased cotton use, and slowed the rate of increase in rayon use. Use of non-cellulosic fibers, however, continued to gain.

Consumer Opinion Studies. Results of studies conducted on consumers' opinions of agriculturally-produced materials in various end uses have been used by natural fiber organizations to evaluate the position of cotton and wool in specific segments of the textile industry, and to encourage and guide private industry's efforts to improve the attributes of natural fibers so that they can compete more successfully with synthetics. In addition, each

year the National Cotton Council of America bases a major portion of its promotion for consumers and retailers on these research results; these reports have also been used as standard examples in the market development program of Cotton Council International.

I. FARM RESEARCH

COTTON CULTURE, BREEDING AND GENETICS, DISEASES, AND VARIETAL EVALUATION

Crops Research Division, ARS

Problem. The American cotton industry faces serious price competition from synthetics and low-cost foreign production. Substantial intensification and expansion of research are needed to reduce costs of production and allow American cotton to compete more effectively in domestic and world markets. There is need for intensive genetics and breeding research to select breeding stocks with useful characteristics such as disease and insect resistance, improved yield and fiber quality, and early maturity, and to develop appropriate methods for the transfer of these characteristics to commercial varieties. Fiber quality research as related to breeding, varietal development and performance, cultural practices, individual properties and their influence on processing performance is necessary to maintain and improve overall quality and to allow for more effective competition with man-made fibers and foreign growths. Cotton is affected by several diseases which cause serious losses in yield and quality and reduce overall production efficiency. Additional emphasis must be placed on the nature and control of diseases in order to overcome this production hazard. Fundamental physiological studies must give consideration to the metabolic processes affecting growth, fruiting and development of the plant and how these processes are influenced by variety, diseases, environment, cultural practices, and applied chemicals. An accumulation of basic information in the above mentioned and related fields is essential to develop applied techniques for increasing the efficiency of producing cotton.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving geneticists, agronomists, pathologists, physiologists, fiber technologists, engineers, physicists, and other scientists engaged in basic and applied research designed to solve problems confronting the cotton-producing industry. The ultimate objective is to lower cost of production, increase efficiency, improve fiber and spinning quality, and thereby make the crop more competitive with synthetics and foreign production.

Research is conducted at Beltsville, Maryland; and in addition, cooperative work is carried out with State experiment stations at Raleigh, North Carolina; Florence, South Carolina; Experiment and Tifton, Georgia; Auburn, Alabama; Stoneville and State College, Mississippi; Knoxville, Tennessee; Fayetteville and Marianna, Arkansas; Stillwater, Oklahoma; College Station, Lubbock, and Ysleta, Texas; University Park, New Mexico; Tempe, Arizona; and Davis, Shafter, and Brawley, California. A field station was recently established at Portageville, Missouri. Federal personnel to be assigned there will work in the cooperative program.

A cooperative agreement is in effect with the Virginia Agricultural Experiment Station, Blacksburg, Virginia, to study mold problems in cottonseed. Cooperative work is also conducted with the Entomology Research Division, the Soil and Water Conservation Research Division, the Southern Utilization Research and Development Division, and the Agricultural Engineering Research Division, all of the Department.

Four P. L. 480 projects are in effect for research on cotton. Two are in Israel and are concerned with (1) the quantitative inheritance of characters influencing yield and lint quality using the diallel cross method and (2) the influence of time and duration of moisture stress on fruiting, yield, and quality. The other two are in India on (1) the parasexual recombination of filamentous fungi with special reference to Fusarium sp. and (2) the effects of gibberellic acid on cotton.

Contributed funds are used in cooperative work with the California Planting Cotton Seed Distributors and Kern County at Shafter, California. Cooperative research is conducted at Tempe, Arizona, on contributed funds from the Arizona Cotton Planting Seed Distributors. The National Cottonseed Products Association contributes to cottonseed research at Shafter, California, and the National Cotton Council of America provides funds for research at Iguala, Mexico; Davis and Shafter, California; and Beltsville, Maryland.

The Federal scientific effort devoted to research in this area totals 78.9 professional man-years. This number includes 22.7 devoted to physiology and culture; 29.0 to genetics and breeding; 16.5 to pathology; and 10.7 to quality.

PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in plant breeding and genetics, plant pathology, plant physiology, agronomy and fiber technology. In many of the States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of cotton.

The Southern States are engaged in the development of breeding stocks to fit the particular needs of local environment. Both medium and long staple upland types are receiving attention. Major breeding emphasis is on fiber properties, particularly length, strength, and uniformity. Types are being bred for greater resistance to Verticillium wilt, Fusarium wilt, seedling diseases, nematodes and blight. Much attention is being given to characteristics to aid mechanical harvesting such as earlier more uniform maturity, smaller plant size, and boll type. Some attention is being given to breeding methodology and attempts are being made to transfer characteristics from related Gossypium species into cultivated cottons. Most of the genetic work to support cotton breeding is being done within

the regional project (S-1), Genetics and Cytology of Cotton, which is very effective in keeping this work coordinated. The Cotton and Cordage Fibers Research Branch participates very actively in this project. Attention is being given to the preserving and cataloging of genetic stocks and propagating them when necessary. Interspecific hybrids are made and followed with cytological and inheritance studies to determine the relationship of species. Other cytogenetic work concerns aneuploids, trisomics, chromosome deficiencies, and chromosome duplications and a larger objective of obtaining a complete set of monosomic lines for cotton. The inheritance of individual qualitative and quantitative traits of cotton are being studied.

In cultural practices the factors that limit yield are being studied as well as the effects of various practices on plant morphology, insect and disease reactions, fiber properties, and weed control. Other factors being studied are the use of winter legumes in cotton rotation, fertilizer levels and rapid tests for determining the germination of cotton seed.

Fiber samples from the breeding and cultural experiments are submitted to State or Federal laboratories for evaluation of fiber and spinning properties. In Tennessee, special attention is given to devising new and better tests and improving equipment for measuring properties now considered standard in fiber testing. Some work is being done to establish end product serviceability relationships to specific fiber properties.

The total research effort on cotton is approximately 65.5 professional man-years; 8.6 is for culture, 37.3 for breeding and genetics, 16.7 for diseases, and 2.9 for variety evaluation.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Culture

1. Flower Initiation and Maturation. Upland cotton is not demonstrably photoperiodic. However, research has shown that the node at which flowering is initiated is under partial environmental regulation. Of particular significance is the discovery that temperature during germination (first 7-10 days after planting) alters the flowering response--low temperature promoting and high temperature delaying flower initiation. Previous research has shown that continued high night temperatures tend to delay flowering. Additional evidence shows that day, as well as night, temperature and length of the high intensity light period are also involved. That the effect is on flowering per se is evidenced by a flowering response to treatment differing in pattern from the effect on overall plant growth rate. These data are significant contributions to the understanding of the causes of variation in flowering patterns of upland cotton with changes in the cotton growing areas. They can be expected to form a part of the eventual bases for selections of breeding stocks best suited for growth in specific areas.

2. Biochemical Mechanisms in Genetics. Continued examination of the nucleotide ratio cytosine/5 methylcytosine (C/5MC) has added further evidence of the species specificity existing within the deoxyribonucleic acid (DNA) molecule. The three additional species studied during the past year represent the C₁, E₁, and E₂ genomes. Genomes now examined include A₁, A₂, B₁, (AD)₁, (AD)₂, C₁, D₁, D₅, D₇, D₂-1, D₄, D₆, D₃-R, D₃-d, E₁, and E₂.

Research on ribonucleic acid (RNA) reported previously tended to support the conclusion that total RNA at the subcellular level did not differ greatly in nucleotide composition from total cellular RNA. Continued studies have been undertaken to explore this concept. Differences in nucleotide composition have been noted in a number of instances. Etiolated (nonchloroplast containing) seedlings have been found to contain guanine-rich polynucleotides of low molecular weight (sRNA) not characteristic of normally green seedlings. In particulate RNA, the nucleotide uridylic acid appeared to be mainly responsible for differences found between green and etiolated tissues. Further studies have been made of the RNA composition of plant parts as related to growth and differentiation. Embryos, floral buds, young leaves, and main stems were found to contain relatively high concentrations of RNA. Leaf maturity and aging resulted in a decrease in RNA and this probably holds for other tissues as well. Differences in RNA composition between plant parts involved the cytosine/adenine ratio. These data are consistent with the hypothesis that RNA is subject to change in nucleotide composition during cell growth and differentiation. Of considerable further interest is the finding that the RNA composition of the nucleus, chloroplasts, and mitochondria (particulate RNA) of cotton cotyledons differs from one another with respect to their salt soluble nucleoproteins. These findings suggest the need for continued research to determine whether similar differences exist in other cotton plant parts of differing activity and age.

3. Mechanism of Abscission. The chemical structure of abscisin II has been determined. It is 3-methyl-5-(1-hydroxy-4-oxo-2,6,6-trimethyl-2-cyclohexene-1-yl)-cis,trans-2,4-pentadienoic acid. Proof of the structure by chemical synthesis has been announced from another source. British researchers have announced that a substance regulating dormancy in sycamore buds called "Dormin" is identical with abscisin II. This group has successfully synthesized the molecule and announced chemical proof of the structure as we reported it. Chemical synthesis by the USDA - University of California research team has been successful in the production of a structure differing from abscisin II only by the lack of two hydrogen atoms, having a triple bond where a double bond should be. This compound showed abscission acceleration equivalent to the abscisin II isolated from young cotton bolls and from which chemical identification was obtained.

In addition to regulation of abscission, abscisin II has now been shown to promote plant aging and to induce dormancy in axial buds of at least some plants. It has been recognized as a plant growth inhibitor since the start of work with this substance by CR personnel. The regulatory nature of the substance was suggested by the observation that its peak growth-inhibiting activity in young cotton fruit coincided with the peak of young fruit abscission. That its activity was not limited to the cotton plant was clearly demonstrated by results showing acceleration of abscission of beans, Citrus, and Coleus plants and recently by its regulation of bud dormancy in sycamore. It appears to counteract the effect of three generally accepted groups of plant hormones, auxins, gibberellins, and rinins.

Work is now underway towards the chemical synthesis of sufficient abscisin II to obtain information on its possible role in the regulation of cotton plant growth and development and to explore its usefulness in cotton production practices and harvesting operations.

4. Germination, Emergence, and Early Seedling-Growth. The establishment of cotton stands and the growth of seedlings during the early part of the growing season, when unfavorable environmental conditions are more likely to be encountered, continue to be a serious problem in cotton production.

Chromatographic analyses of the liquid endosperm of 12-14-day-old cotton embryos produced evidence of a naturally occurring high concentration of malic acid (in excess of 7 gm per liter). Addition of this substance to in Vitro culture media resulted in a high degree of viability and a more rapid growth rate of early stage cotton embryos. The calcium or ammonium salts were active; whereas, the sodium salt retarded or inhibited growth--indicating the probable existence of a complex requirement for this substance. Malic acid has also been found to partially offset the need for high osmotic pressures in the nutrient solutions.

Investigations designed to characterize the effect of low temperature on emergence and early seedling growth have demonstrated the existence of potentially long term effects of cold injury. Chilling treatments applied after one day of germination at 87° F. reduced plant height and final yield at harvest and such other growth and development characteristics as first internode length, time to first bloom, and earliness. Additional studies indicate that the emerging seedling is most susceptible to injury after initial primary root elongation but prior to hypocotyl elongation which forces the cotyledons above the soil surface.

During later stages of seedling growth, root temperature appeared to be more important than air temperature in affecting survival potential of cotton seedlings. Chilling the roots at 59° F. caused decrease in the concentrations of ribonucleic acids and soluble proteins in shoots and a rapid increase in sugar content throughout the seedlings. Cooperative research with pathologists also indicates that growth of seedling

disease fungi is favored by the resulting high concentrations of sugars in the stems. Sap extracted from stems of cold-grown seedlings contained more sugar and supported greater growth of the disease fungi, Rhizoctonia and Pythium, than sap extracted from stems of seedlings grown at favorable temperatures.

Chilling at 34-41° F. caused severe injury to leaves of unhardened seedlings. Injury was accompanied by a rapid decrease in soluble protein. However, seedlings could be hardened by a preconditioning at 59° F., so that little injury was evident after severe chilling. Hardening also prevented the rapid decrease in soluble protein content mentioned above.

5. Harvest-aid Chemicals and Procedures. Labeling for limited use of a new desiccant material, Ammonium Nitrate, has been requested for California as a result of research carried on at Shafter. The usefulness of this material in other parts of the Cotton Belt is currently being evaluated.

The continued loss of cotton yield and quality to boll rots has maintained interest in bottom defoliation and other chemical and mechanical means for reducing the hazard. In Mississippi, defoliant application to the lower 24-26 inches of the plant has not adversely affected yield or quality after 20 percent of the bolls are open. Addition of suboptimal rates of defoliant with the last insecticide application delayed crop maturity and adversely affected fiber and seed quality. Topping (removal of the terminal 4 inches of the plant) or lateral pruning treatments have been studied with presently unequivocal results which do not appear too promising. Joint physiology-pathology studies of causes and factors affecting incidence of boll rots are in process at Shafter, California. Research has been completed on the effect of external carbohydrates from bolls at two locations--Buena Vista, where a high incidence of boll rots is characteristic, and at Shafter, California, where their incidence is low. Percentage spore germination and carbohydrate concentration were lower at Buena Vista than at Shafter. The lack of correlation either by location or time of sampling indicates that carbohydrates on boll surfaces play little, if any, significant role in boll rot incidence or development. The data do, however, suggest that boll rot inhibitory and stimulatory substances may occur on boll surfaces. If these results are confirmed, isolation and identification of the substances involved will represent a significant contribution to the understanding of boll-rot-pathogen-plant relations.

No growth-retarding chemicals currently show promise of being useful for the control of second growth.

6. Plant Responses to Pests and Pesticides. The need for careful evaluations of possible deleterious interactions when combined pesticide applications are made to cotton was pointed out in last year's report. Continued studies of the effects on cotton of the materials involved (the herbicide monuron and insecticide Di-syston) have shown that Di-syston

reduced water uptake by the plants and perhaps as a result, reduced carbohydrate content. Monuron above 10 ppm produced leaf necrosis. Changes in nitrogen and phosphorous content were also investigated. However, no concrete evidence for the existence of the observed interaction between the two pesticides was obtained.

The need for practical methods for use of systemic insecticides has occasioned a series of cooperative investigations by physiologists and entomologists on the fate of selected systemic insecticides when applied locally to various plant organs. Stem applications of various types have been found a useful tool in studies of absorption and transport mechanisms. Research with the insecticide SD-9129 has shown accumulation in cotton leaves to be directly correlated with leaf weight at the time of application as a complete band to the lower stem. Application to one side of the stem resulted in accumulation mainly in leaves on the treated side. Experiments employing girdled plants of varying types suggest that absorption and movement occurred in three stages: (1) Lateral diffusion into the cortex, (2) lateral transport in medullary rays, and (3) vertical transport via the phloem and xylem with the xylem as the main medium of transport.

Understanding of the mode of action of systemic pesticides has necessitated studies of the arrangement and continuity of xylem in the Upland cotton plant. Basic dyes have been used to trace xylem element patterns of distribution and accumulation in leaves. Patterns of movement and distribution were found similar to those reported above for insecticides. The interconnection of xylem elements between leaves, stems, and roots is greater on the same side of a stem than on opposite sides. Specific areas of a leaf blade are supported by xylem bundles that maintain their separate identity at least as far back as the main stem of the plant.

Spraying very young cotton seedlings with methyl parathion delays fruiting branch initiation by approximately two nodes. This delay was found to be positively correlated with a reduced first picking at harvest time. Final yields were unaffected. The phosphate containing insecticide, phorate, was found in greenhouse tests to induce similar cotton plant responses.

7. Plant Responses to Environment. Excavations to study root development have shown that fields with hardpan produce plants characteristically without well-developed tap roots, but with a higher lateral root density in the surface foot of soil. Studies of the role of the tap root in plant and crop development were made in precision-tilled fields by mechanically severing tap roots in the seedling stage. Plants with pruned tap roots had a greater number of laterals. No evidence was found of a lateral assuming dominance and in effect replacing the severed tap root. Final plant height was unaffected. Seed cotton yields were reduced 33 percent.

Recent studies at Shafter, California, of the effect of row direction in skip-row cotton have indicated that increased yields observed in outside rows are in part at least a function of increased light interception. To study light intensity effects, cotton was grown (1) under nylon mesh (6,000 ft. candles), (2) in full sunlight (10,500 ft. candles), and (3) with 2 x 16 ft. sheets of polished aluminum positioned in such a way as to reflect maximum light on the test plants (16,000 ft. candles). As the intensity of light increased, an increase in total number of flowers, bolls, percent retention, and yield of seed cotton was observed. On a per acre basis, shaded plants produced 2,405 lbs. seed cotton per acre; full sunlight, 4,740 lbs.; and with aluminum reflectors, 4,461 lbs.

Effects of lodging on crop yields have been the subject of numerous studies in crops other than cotton. A recent study in California on cotton artificially lodged on August 4, September 1, and September 15 has yielded the following information: (1) Cotton plants lodged August 4 yielded 50 percent less than nonlodged plants; (2) on September 1, 20 percent less; and (3) on September 15, 10 percent less. Growth and flower production were also reduced; and lodging adversely affected the fiber length, uniformity, fineness, and maturity.

There are 22.7 professional man-years devoted to physiology research.

B. Breeding

1. Regional Cotton Variety Testing Program. Results from the Eastern, Delta, Central, Plains, Western, and extra-long staple (Pima) regional tests from the 1963 crop were published in ARS 34-68. Approximately 1,000 copies of the report were distributed. The mailing list includes cotton breeders, producer organizations, merchants, textile firms, and agricultural libraries. These tests are conducted at 40 locations throughout the Cotton Belt. The analyses of the extensive data drawn from samples over this wide area provide estimates of the inherent differences among varieties with a high degree of statistical reliability.

Agronomic, fiber, and spinning data from the 1964 crop are being analyzed.

2. Cotton Winter Breeding Facility, Iguala, Mexico. This facility for providing a tropical location for growing experimental cottons during the winter is in its fifteenth year of operation. It continues to grow in service and usefulness in support of cotton research programs of the United States. During the 1964-65 season, 41 public and private research organizations requested over 8,000 cross-pollinations and approximately 15 acres of self-pollinated material. The ability to grow a second generation each year in the tropics accelerated research, and is more economical and effective than comparable work in greenhouses in the Cotton Belt.

3. Release of Seed Stocks. The New Mexico and Arizona Agricultural Experiment Stations and the U. S. Department of Agriculture jointly released Hopicala, a productive variety with excellent fiber properties. Although this cotton was bred in New Mexico, extensive testing over the Western region indicated that it was well adapted in Arizona. It yields well in New Mexico, but because the fiber length is about 1/16 inch shorter than that of the Acala 1517 types, it is not recommended in the El Paso trade territory. Fiber of Hopicala is as long as varieties currently grown in Arizona. Its higher tensile strength gives it a significant advantage in quality as measured by yarn strength. The development of Hopicala illustrates the advantages of cooperative effort among agencies and the effectiveness of regional testing.

4. Extra-long Staple Breeding. Research on the reaction of Pima strains to environmental differences in the production area has led to the development of a plant-typing scheme which makes selection for varietal improvement more effective. Pima cotton is grown from Yuma, Arizona, to Pecos, Texas, at altitudes ranging from 100 to 4,000 feet. During the fruiting season for cotton, the lower elevations are characterized by high temperatures during both day and night; whereas, at the higher elevations, the day temperatures are high but night temperatures are moderate. Typing is based on the height of the fruit set on the plant. In general, plants grown at the high elevations set fruit lower, and differences among strains are not great. At the low elevations, differences among strains become so exaggerated that some strains fruit exceptionally well while others produce a tall, rank, vegetative plant with reduced yield. Understanding of this strain environment response makes selection programs at the different altitudes more precise. Progress is already being made in selecting strains which are not influenced by environmental differences due to altitude.

The Pima industry has had some difficulty with bales of Pima S-2 falling below the 1-3/8 inch staple length required by law to qualify for the extra-long staple marketing program. Breeders are attempting to increase staple length without lowering the high yield potential of Pima S-2. In 1964, the performance of several advanced strains in yield, staple length, and spinning performance justified preliminary increase of seed stocks. If subsequent testing indicates that new varieties should be introduced, substantial quantities of breeder seed will be available.

5. Glandless (gossypol-free) Cottonseed. Gossypol in ordinary cottonseed products is an expensive nuisance to the cottonseed crushing industry and limits the usefulness of cottonseed products. Research by oil chemists and nutritionists has shown that oil and meals from glandless cottonseed are superior to ordinary cottonseed products.

Breeders are attempting to combine the glandless trait with the complex of desirable characters necessary in a commercial variety. Performance of

glandless strains in tests in 1964 was variable and exhibited about the same range of variability as newly selected glanded strains. Glandless strains, in some cases, performed as well in yield and fiber properties as check varieties. Foreign requests for information on glandless inheritance and for breeding stocks indicate that glandless cottonseed is a potential new source of protein for human consumption. This would be particularly significant in protein-deficient areas of the world where cotton is grown.

6. Insect Resistance. Screening of cotton germ plasm for biochemical and mechanical factors influencing insects continued. Over 300 lines were screened for low rate of boll weevil oviposition. An inheritance study of factors causing boll weevils to oviposit at low rates on selected cotton lines was begun. The F_1 hybrid between lines eliciting high and low ovipositing by weevils was as low as the low parent. Glanded and glandless versions of two varieties were exposed to uncontrolled insect attack in field plots throughout the growing season. Boll weevils showed no preference; boll worm damage was more severe on glandless strains than on the glanded counterpart for one variety, but in the other variety, this difference was not observed. In other observations, leafworm and certain species of beetles favored glandless cotton. Combinations of smooth leaf, nectariless, and glandless were developed in order to study the combined influence of these three characters on insect preference.

7. Breeding for Improved Fiber Quality and the High Quality Regional Test. It has not been possible to duplicate in the Southeast and Midsouth the yield-quality combinations now enjoyed by the El Paso trade territory and the San Joaquin Valley of California. Breeders in the Southern and Southeastern areas have made progress in improving the yield of high-quality cottons over a long period of years to the point where a comprehensive evaluation of the status of these cottons was justified.

In 1964, a special High Quality Regional Test was conducted at nine locations in eight Southeastern and Midsouthern States and represents joint work with Quality Investigations. Entries were restricted to commercial check varieties and to experimental strains with spinning performance significantly superior to current varieties grown in the area. Considering the region as a whole, the highest-yielding experimental strain yielded 90 percent of the best commercial check. In more localized situations, experimental strains equalled the yield of commercial checks in several cases. The better high quality strains are at about the same yield level of commercial varieties grown 5 to 10 years ago. In recent years, new commercial varieties have advanced the yield of cotton varieties of average quality, and even though the yield of high-quality strains has advanced, a yield differential still exists. In other words, we are trying to overtake a moving target. A Regional High Quality Test for 1965 will be conducted.

The progress in breeding seems to coincide with a sharp increase in concern and interest in the industry for quality improvements. Factors responsible for this increased interest are: (1) Movement of Western Acala production into free trade at premium prices 3-5 cents per pound over Government loan values, (2) failure of large amounts of southern cotton to reach the market except through Government loan, (3) increased requirements for textile raw materials made necessary by faster processing rates in mills and deteriorating influence of "wash-wear" and other chemical and physical treatments, (4) competition from synthetic fibers and foreign cotton, (5) realization that improved yield-quality combination may be a feasible breeding objective, and (6) development in instruments and spinning evaluation techniques to permit rapid testing for quality factors.

8. Basic Cotton Genetic Studies. The accumulation of germ plasm, the genetic analyses of characters, and the identification and manipulation of chromosomes increase the opportunities and ability of breeders to improve cotton varieties. Basic work in the past has provided materials and knowledge which are of practical use in current agricultural varieties. Potentially useful characters have been discovered which provide the stimulation for further research.

Results for 1964 were summarized in the Annual Report of Cooperative Regional Project S-1, Genetics and Cytology of Cotton. The master project was revised to reflect changes in emphasis and responsibilities among the several States and the U. S. Department of Agriculture. The results are concerned with many technical findings too numerous to list in this report, and only highlights will be mentioned.

Virtually all of the germ plasm collection of roughly 1,400 stocks has been placed on deposit at the National Seed Storage Laboratory. Evaluation of introductions for insect resistance, disease resistance, fiber properties, and photoperiod response continued.

Additional monosomes (plants lacking one chromosome) were found and identified. A chromosome substitution program was begun to utilize the monosomes to transfer, intact, single chromosomes from hirsutum into barbadense and barbadense into hirsutum. New interspecific hybrids were synthesized to further clarify the relationships among the species. The program to mark each of the 26 cotton chromosomes with homozygous translocations (rearranged chromatin which can be recognized microscopically) was advanced by finding six new translocations.

The inheritance of new mutants and the linkage relationships among many loci were reported. A case of male-sterility involving interaction of a gene and foreign cytoplasm was discovered. Preliminary data indicate that hard, impermeable seed is inherited as a single dominant factor. Isogenic lines for eight dominant characters were stabilized after eight backcrosses and 18 other marker genes are in the program to build isogenic lines.

Quantitative inheritance was indicated for smooth leaf of Yugoslavian origin, internode length, and strong stalk. Random mating for six generations was partially effective in breaking up undesirable linkage combinations among quantitative characters. Factors for early maturity were not significantly correlated with fiber quality factors. The effectiveness of recurrent selection for advancing mean yields and mean tensile strength was demonstrated.

Potentially useful characters are often found in stocks which are otherwise inferior to the cultivated varieties. It is necessary to transfer genes for these factors in various varietal backgrounds. Factors now being transferred by backcrossing to established varieties include smooth leaf, nectariless, glandless, and root-knot nematode resistance.

Under P. L. 480 project in Israel, agronomic data previously reported are being supplemented by fiber property data. Micronaire values of interspecific barbadense x hirsutum hybrids were significantly lower than those of the parental varieties. This is an important finding relative to the potential use of interspecific hybrids in the United States.

There are 29.0 professional man-years devoted to genetics and breeding research.

C. Diseases

1. Bacterial Blight. Research has shown that by combining the blight resistance genes, B₂, B₃, B₆, in a single plant, the result is virtual immunity to the angular leaf spot, black arm, and boll rot phases of bacterial blight. This discovery is of importance to growers, and basic breeding stocks are now available to the breeders so that new varieties being developed can carry this type of resistance. The fact that other resistance genes have not previously imparted resistance to all three phases makes this discovery of particular importance, because yield and quality losses from the boll rot aspects of the disease are reduced to a minimum or eliminated entirely. The blight eradication program in California apparently is completely successful since no incidence of the disease was reported in 1963 or 1964. Research is now in progress to determine the relationship of DNA produced by the various strains of the organism, and there is hope that this information will provide the key to further reduction in the damage caused by this disease. The work on antigens in the parasite as they relate to host specificity was concluded and the results published in 1964.

2. Fusarium Wilt. Expanded use of Fusarium wilt-resistant varieties in the Southeastern States is continuing to reduce the production hazard from this disease. Bacterial blight resistance has been incorporated in several of the Fusarium-resistant varieties and basic breeding stocks; thus, enhancing their value to the growers and cotton breeders. Basic studies on

population dynamics of nematodes usually associated with Fusarium wilt have provided new information, which is being used as a breeding tool in work now under way on the Fusarium nematode complex. The Fusarium wilt screening service provided under this program is continuing to raise the general level of Fusarium resistance in the commonly used southeastern varieties. Private, State, and Federal cotton breeders continue to use this service in critical evaluations of their Fusarium wilt selections. The program of incorporating nematode resistance into Fusarium-resistant varieties is continuing, and definite progress is being made in the development of breeding stocks which carry this combination of resistance factors.

3. Verticillium Wilt. Controlled laboratory and greenhouse studies have provided valuable information on the role of the several soil microorganisms involved in the severe Verticillium wilt syndrome, which has occurred in extremely damaging proportions over large areas of the productive San Joaquin Valley in California. Thielaviopsis, which is often associated with Verticillium in the soil, has been shown to produce an additive or even a symbiotic effect. This information is of considerable value to the plant breeders since they can now direct their efforts to utilizing known resistance genes to Thielaviopsis in the development of selections more resistant to Verticillium wilt. Basic research on the nature of resistance to Verticillium wilt is being emphasized because of the encouraging results obtained thus far. Studies on the behavior of germinating and developing conidia in xylem fluid collected from tolerant and resistant plants indicate that the kind and amount of nutrient elements supplied to the plant have a definite effect on the host pathogen interaction. Certain of the amino acids have been found inhibitory to the development of the fungus, and it is felt that this offers a fruitful area of research for developing resistant varieties on a precise basis. The microbiological approach to Verticillium wilt has been reactivated, but further work in this area is required before positive results can be reported.

4. Disease-Nematode Complexes. Research has shown a positive relationship between the type of nematodes present in the soil and the severity of the seedling disease complex. The information developed from these studies will be used by the cotton breeders to incorporate the highest degree of nematode tolerance and Fusarium wilt resistance into the varieties which will minimize seedling losses from this cause. The screening techniques developed under this program are being used to make selections from segregating populations--those individuals which carry the highest degree of Fusarium resistance and nematode tolerance. From these studies, it has been found that certain species of nematodes are associated with specific diseases while others do not contribute materially to the disease syndrome.

5. Seedling Diseases of Cotton Including Cold Tolerance. The first step in reducing production costs depends upon obtaining and maintaining a uniform stand of vigorous plants. Research on the use of soil fungicides as a supplement to seed treatment has shown that this is an economically feasible and highly profitable approach to seedling disease control. The types of materials and methods of application developed under this program have been enthusiastically received by the growers, and it is estimated that approximately three million acres received this type of treatment in 1965. Continued progress is being made on the selection of lines of cotton which produce normal seedlings at temperatures which are below that at which current varieties will develop. The increased vigor of the cold-tolerant seedlings appears to impart a certain degree of seedling disease resistance or escape, either of which will provide a uniform stand of vigorous plants under conditions where unselected lines would succumb.

6. Boll Rots. Controlled studies on microclimate effect on the incidence and development of boll rots are providing valuable information on the edaphic and environmental conditions, which are likely to produce severe losses from boll rot. Studies on the use of fungicides alone and in combination with bottom defoliation have shown that levels of control can be obtained which would be economically profitable to the grower. Laboratory studies have also shown a relationship between cultural practices and boll constituents which influence the severity of boll rots. Studies are now in progress to explain the role of these practices individually and in combination on the boll constituents and also on the boll rots. It is hoped that the results from these studies will be helpful in the development of cultural practices which will minimize losses from this production hazard.

There are 16.5 professional man-years assigned to the cotton pathology problems.

D. Quality and Varietal Evaluation

1. Automation of Fiber and Spinning Tests. Progress has been made toward automating fiber testing at the USDA Laboratory, Knoxville, Tennessee. An assembly line has been placed in operation with tests for length (digital fibrograph), fineness (micronaire), color (colorimeter), and a visual measure for trash. Data are automatically recorded on punch cards, processed through a computer, and print-out results sent to the cooperators. Present instruments for measuring strength cannot be run at the same speed as the above-mentioned measurements; however, operations have been set up with the stelometer to record breaks and weights of the broken samples directly on punch cards. Calculations and adjustments to standards are then made by computers and stelometer measurements can be included as print-outs.

A contract is now in operation with the University of Tennessee on the design of a new strength tester so that this measure can be made with speed and accuracy equivalent to the measurement of other properties in an automated assembly line. The first phases of this work have involved the design of new clamps. Satisfactory clamps have recently been made with metal-to-metal surface holding the fibers, thus eliminating variability caused by wear and lack of uniformity in leather surfaces.

This has been the second year that the spinning laboratory has been completely in operation with the present automated assembly line. The number of 50-gram spinning tests is now above 8,000 per year, most of which are processed within four months. There has been a 300 percent increase in numbers since the 1960 season. Samples through the spinning test are now processed at the rate of 7 per operator per day. The increased production has made it possible to spin replicated samples from variety and strain tests, and to analyze yarn strength routinely by appropriate statistical analyses. Replicated samples have been run and analyzed on the Regional Variety Tests since 1961. Within the past two years, all major variety and advanced strain tests in USDA and cooperative State programs were spun at Knoxville.

2. Infection Phenomena Relating to Microbial Deterioration of Cotton Fiber in the Field. Several aspects of the subject of microbial deterioration of cotton fiber in the field have been investigated in the Branch over a period of years, notably matters relating to: (1) The kinds of changes which microbial action causes in the fibers, (2) the development of test methods which are of practical value in detecting such changes, and (3) the processing performance of field-deteriorated fiber through cooperative studies with SURDD. Much less has been known about just how microorganisms infect the fiber in the field. Observations at Florence, South Carolina, in 1964 indicated that in many cases organisms causing fiber deterioration entered the bolls either through a normally cracked suture at the time of boll opening or through the pedicel prior to boll opening. Fungal infection of both the nectaries and the bracts was common, but the tissue in which the nectaries are embedded and to which the bracts are attached was especially resistant to rot, apparently barring fungus growth by this route to the fiber inside the unopened boll. Many rotting flowers adhered to the tips of near-mature bolls, but under the conditions observed, no evidence was noted for infection through the flower into the tip of the boll and by this pathway to the fiber inside the boll.

Rotting of the boll and fiber is often most severe near the base of the boll. Prior to any rotting, however, a rusty-brown discoloration was found internally in many bolls at the point of attachment of the pedicel to the boll. It is thought that early senescence phenomena in this sterile discolored tissue may predispose the affected cells to microbial infection, which may then spread internally upward from this point into the fiber and seeds. Further relevant observations are needed on the general subject of infection phenomena relating to microbial deterioration of cotton fiber in the field.

3. Attempts to Detect a Cellulose-Decomposing Enzyme in Higher Plants. Prior reports from other laboratories have indicated that a cellulose-decomposing enzyme occurs in the tissues of several higher plants; i.e., tobacco, alfalfa, Bermuda grass, etc. Fairly extensive tests on a variety of higher plant tissues in our laboratory have failed to date to yield a single case providing clear evidence for the existence of such an enzyme in a higher plant. The best present conclusion seems to be that prior conclusions on this point were incorrect because the investigators overlooked either one or both of the following points; namely (1) the plant tissues tested were already infected with microorganisms before the test period, or (2) the plant tissue preparations were contaminated with microorganisms which grew during the cellulase assay. When never-dried cotton fibers from a mature but unopened boll were allowed to stand under sterile conditions for a week, there was no evidence of cellulose breakdown.

4. Mycotoxin-Producing Fungi in Cotton Seed at Harvest. Large-scale losses of young turkeys in England in 1960, after ingestion by the birds of moldy peanut meal, were traced to the infection of the meal by Aspergillus flavus. It was further determined that this fungus produces at least four highly toxic compounds, of which at least one is an extremely potent carcinogen. These findings aroused widespread interest in the general subject of mold-produced toxins in seed and other plant parts which may be eaten by man or animals. Little is known about this subject in relation to cottonseed, and investigations were initiated to determine the kinds of fungi which invade cottonseed prior to harvest and the toxin-producing potentials of such fungi.

Collections of seed-cotton were made from the 1964 crop at several locations across the U. S. Cotton Belt. Examinations to date have revealed the following fungi as common causes of internal infection: Fusarium spp., Alternaria sp., Colletotrichum gossypii, Diplodia gossypina, Nigrospora oryzae, and Aspergillus niger. Among the less common causes of internal infection have been Cephalothecium spp., Rhizopus, sp., Curvularia sp., and Aspergillus flavus. Of these several fungi, isolates of Fusarium spp., Alternaria sp., and Aspergillus flavus have been associated under some conditions by previous workers with the formation of mycotoxins. No highly critical data can be given on the frequency of occurrence of Aspergillus flavus in cottonseeds at harvest, but the frequency seems to be low in collections examined to date. Numerous samples of seed incubated in pure culture with various of the above fungi and samples of seed collected in the field have been prepared for later mycotoxin analysis and toxicological examination by the Virginia Agricultural Experiment Station through a cooperative agreement.

There are 10.7 professional man-years devoted to quality and varietal research.

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CORDAGE FIBERS CULTURE, BREEDING AND GENETICS,
DISEASES, AND VARIETAL EVALUATIONS
Crops Research Division, ARS

Problem. The United States depends almost entirely on imports to meet its needs for jute, abaca, sisal, and henequen. In 1964, approximately 73,000 tons of jute valued at \$10 million and \$173 million worth of manufactured jute products were imported from India and Pakistan. In addition 127,000 tons of hard fibers valued at \$35 million were imported primarily from the Philippines, Mexico, Brazil, Haiti, and Kenya.

The domestic production of kenaf, a suitable substitute for jute, is dependent primarily upon the development of a higher yielding variety that is resistant to root-knot nematodes, and upon the development of machinery that would reduce the cost of harvesting and processing. Additional information on breeding behavior of the numerous Hibiscus sp. is needed in order to develop a high-yielding, disease-resistant variety of kenaf. High-yielding, cold-tolerant sansevieria hybrids, which produce a fiber suitable as a substitute for abaca and sisal, can be grown in southern Florida; however, the availability of sisal, henequen, and abaca at low prices and the lack of labor-saving machinery for harvesting preclude the possibility of domestic production in peace-time.

An interesting development in Florida, Georgia, and Alabama is the use of kenaf in paper pulp. Several paper companies conducted experiments with kenaf and found it to be suitable as a source of pulp for tissue paper. Their preliminary experimental results are most encouraging. The increasing demand for paper and the decreasing pine stock are causing paper companies to seek other sources of pulp material. Kenaf can be grown throughout the agricultural area of Florida on land that is used only to produce winter vegetables. Producing a kenaf crop in 100 days gives it an economic advantage when compared with the production of pine which requires 25 years. Much work needs to be done in developing varieties more suitable for pulp even though results with fiber types have been promising. Additional information is needed on cultural requirements that affect pulp quality.

USDA AND COOPERATIVE PROGRAM

The Department's program with cordage fibers involves breeding, genetics, diseases, culture, and varietal evaluation.

The work is cooperative with the University of Florida Everglades Experiment Station and the Agricultural Engineering Division at Belle Glade, Florida. Kenaf varietal testing was cooperative with the University of Georgia at Experiment, Georgia. Industry conducted research in northern Florida on the use of kenaf for pulp.

The Federal scientific effort devoted to research in this area totals 3.0 professional man-years. This number includes 1.0 devoted to pathology, 1.0 to genetics, .5 to culture, and .5 to quality and varietal evaluations.

PROGRAM OF STATE EXPERIMENT STATIONS

The research on cordage fiber crops in the States is carried on as part of the projects on new or replacement crops. Attention is given to adaptation of available varieties and their performance under various cultural practices. No research was identifiable under the heading of cordage fibers.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Kenaf. Thirteen species of Hibiscus were screened for resistance to root-knot nematodes. Six species were highly resistant, six were moderately resistant, and one H. cannabinus (kenaf) was very susceptible. However, a wild strain of kenaf, P.I. 292207 introduced from Kenya, was significantly more resistant than other strains of kenaf. P.I. 292207 was successfully crossed with several cultivated strains.

In further attempts to obtain a root-knot-resistant fiber type, a large number of crosses were made between the susceptible H. cannabinus and the resistant H. sabdariffa. Four hybrid plants were recovered. New interspecific combinations were made between H. costatus x H. aculeatus, H. cannabinus x H. meeusei and H. asper x H. meeusei.

One professional man-year is devoted to breeding and genetics research.

B. Diseases

1. Kenaf. During late winter and early spring of 1964 Botrytis sp. severely attacked kenaf, Hibiscus cannabinus, and roselle, H. sabdariffa, near Lake Worth, Florida. The severity of the disease was such that the question arose of the extent of development of this disease on other crops in Palm Beach County. A survey revealed a rather widespread distribution of Botrytis sp. on pepper, eggplant, tomatoes, and certain varieties of gladioli. Specimens of Botrytis were also collected from beans, strawberries, potatoes, and chrysanthemums and African violets.

Cross inoculations of the various plants from which cultures of Botrytis were obtained revealed that infection was obtained from the kenaf culture on roselle, tomato, pepper, and eggplant. Kenaf was also infected by cultures from these plants. The kenaf fungus infected potato tubers and bean pods; the fungus from potato and beans did not infect kenaf. The kenaf fungus did not infect gladioli, strawberries, African violets, or chrysanthemums, nor did the fungi isolated from these plants infect kenaf.

Sclerotia were formed by the fungi isolated from kenaf, roselle, pepper, eggplant, tomato, potato, and beans, when inoculated into pink tomato fruits and held at 20-24°C. The temperature response varied slightly among the different isolates.

Preplant indexing of soil from Marianna, Florida, indicated correctly that kenaf would be attacked by root-disease fungi and root-knot nematodes if planted in this soil. Prediction that kenaf would be relatively root disease free planted at Experiment, Georgia, was confirmed by performance of kenaf at that location. A combination of pythiaceous fungi isolated from soil particles and observations of seedling roots grown in soil samples collected from the respective locations and brought to Belle Glade, Florida, was used in the index procedure.

Soil fungicide-fumigants were from 20 to 50 percent as effective in muck soil as sandy soil; relative to distance, Rhizoctonia sp. were controlled outward from point of injection in the soil.

One professional man-year is devoted to disease research.

C. Quality and Varietal Evaluation

1. Kenaf. Kenaf strain trials were conducted at Experiment, Georgia, and Belle Glade, Florida. The varieties, Everglades 41 and Everglades 71, continued to be superior in yield of fiber at Belle Glade, Florida; however, they were inferior in yield to the variety BG 52-52 when grown at Experiment, Georgia.

.5 professional man-year is devoted to quality and varietal research.

D. Culture

1. Kenaf. Kenaf grown on Everglades peat in 7-inch uniformly spaced rows and 7-14-7-inch skip rows yielded significantly more fiber than those grown in more widely spaced and uniform rows and skip rows (14, 21, 14-28-14, 21-42-21). Plants grown in uniformly spaced rows yielded higher on the average than those grown in skip rows.

Two NPK factorial kenaf fertility experiments were conducted in Florida, one on Immokalee fine sand and one on Everglades peat. Application of 150 pounds of N on the sand and of 50 pounds per acre on the peat resulted in the highest fiber yields. The application of 200 pounds per acre of K on the sand and 150 pounds on the peat resulted in highest fiber yields. The application of P had no significant effect on fiber yields.

In order to determine the effect of date of planting on yield of seed, the variety Everglades 71 was planted at 10-day intervals beginning August 10 and continuing until September 29. Yields per acre decreased from 1395 pounds for the earliest date to 103 pounds for the latest date. Everglades

71 planted in 7" rows and plants spaced 5" apart in the row gave significantly higher seed yields than any other row width or plant spacing studied in a row width and plant spacing experiment.

.5 professional man-year is devoted to culture research.

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WEED CONTROL
Crops Research Division, ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. The national annual loss in agricultural production due to weeds has been estimated to be about \$2.5 billion, and the annual cost of controlling weeds is an additional \$2.6 billion. The control of weeds is the most critical economic problem in many phases of agriculture. Improved weed control methods will facilitate farm mechanization, greatly increase production efficiency, and improve the efficiency of the use of human and land resources in agriculture. Detailed information must be obtained on the nature, growth, and development of weeds so that any weaknesses in the reproduction, spread, and survival characteristics of weed species can be exploited in developing methods for their control. More effective and selective herbicides are needed. Fundamental studies on the physiological and biochemical responses of weeds and crops to herbicides will provide information on the relation between molecular structure of herbicides and their modes of entrance, movement, behavior, metabolism, persistence, and fate in plants and soils. This information is essential to the development of new, more effective, and more selective herbicides and formulations of herbicides and for their efficient safe use. Information is critically needed to develop safe and effective methods of using new herbicides that avoid or minimize the accumulation of chemical residues. Information is required on the effect of environment, soil, plant structure, and method and time of herbicide application, and on the effectiveness of herbicides and their persistence in and on crops and soils. Research is critically needed on the integration of chemical and chemical-cultural methods of weed control into mechanized crop production practices, including the development of herbicide-crop rotations that prevent the accumulation of herbicide residues in soils and reduce the risk of injury to subsequent crops in the rotation.

USDA AND COOPERATIVE PROGRAM

The U. S. Department of Agriculture has a continuing long-term program of basic and applied studies directed toward the solution of weed problems on farms, irrigation canals, ponds, rights-of-way, and other areas where weeds and brush are problems. Research on reducing damage to crops by weeds includes studies of the life histories and growth patterns of individual weeds and the use of cultural methods, biological agents, and herbicides for their control. Weed research includes physiological and biochemical studies to determine the mechanisms involved in absorption and translocation, the mode and site of action, the effect of environment on plant responses to herbicides and the metabolism and fate of

herbicides in plants and soils. Comprehensive studies are made to develop principles, practices, and methods of using herbicides and other weed control techniques in solving regional agricultural weed and brush problems in agronomic crops, horticultural crops, grazing lands, and aquatic and noncropland sites.

All the research on the control of weeds is conducted cooperatively with State Agricultural Experiment Stations with the exception of the research at Beltsville, Maryland; Denver, Colorado; and Mayaguez, Puerto Rico. State Agricultural Experiment Stations usually furnish office, laboratory, and field facilities, as well as funds and other assistance in support of the cooperative research. There is cooperation also with other Federal agencies, including the Bureau of Reclamation and Bureau of Land Management, Department of the Interior; Forest Service of the Department; United States Army Corps of Engineers, and the Advanced Research Projects Agency, Department of Defense; and Plant Pest Control Division of the Department, which ranges from informal contributions to providing funds and personnel in support of weed control research. Industrial companies cooperate in furnishing experimental chemicals, equipment, and funds essential to rapid progress in weed control investigations. Certain private or semipublic groups, including the National Cotton Council of America, the Central and Southern Florida Flood Control District, and the California Department of Water Resources, furnish financial support of cooperative research on weed problems.

The total Federal scientific effort devoted to weed control research is 78.2 professional man-years. This includes 11.0 professional man-years supported by contributed funds, and 12.2 professional man-years in contracts, grants, and cooperative agreements with other institutions. Of the total, 16.5 is devoted to physiological and ecological basic research at Beltsville, Maryland, which is broadly applicable to all crop commodities, and similar studies are conducted at most field locations; and 8.8 professional man-years are devoted to weed control in cotton.

PROGRAM OF STATE EXPERIMENT STATIONS

All the State Experiment Stations are conducting basic and applied research in weed control. These studies involve evaluation of selective herbicidal properties of new chemicals to show the relation between chemical structure, herbicidal activity, and weed-crop selectivity; the nature, behavior, and effect of herbicides on their degradation products in and on plants and plant products; the mechanism of herbicidal action; influence of climate, plant morphology, and soil characteristics on the effectiveness of herbicides in selectively controlling weeds and on their persistence

in plant tissue. The State Experiment Stations are directing a large amount of effort toward the development of practices for the selective control of weeds in crops, pastures, and rangelands. Studies are being conducted on the movement and persistence of herbicides in various soil types and the phenomena involved in absorption and other interaction of herbicides with clay complexes.

Weed life cycles and growth habits are being studied under different environments to determine the most susceptible stage of vulnerability to herbicides and other control measures. Other aspects that are currently being investigated are: Competition between weeds and desired plant successions following control measures including replacement vegetation and management practices. Relation between weeds and biological control organisms that attack them in different environments is being studied on a limited scale.

Much of the basic research in weed control is being done via six regional projects as follows: W-52 is exploring the fundamental biochemical and biophysical processes involved in herbicidal action; W-77 is studying the chemical and physical properties of herbicides in relation to environment and effectiveness; NE-42 is investigating weed life cycles and light as factors in weed control; NC-61 is concerned with the nature and extent of competition between weeds and crops; S-18 and NE-42 are investigating the behavior of herbicides in soil, the physiological aspects of certain herbicides and life histories of important southern and northeastern weed species. CRF-1 program is attacking basic problems in aquatic weed control and brush control. The USDA cooperates on much of this research activity.

The total State scientific effort devoted to weed control research is 357.0 professional man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. General

1. Herbicide Evaluation Studies. More than 75 chemicals were evaluated in the greenhouse on 8 plant species at 2 rates of application as soil-incorporated, pre- and postemergence treatments. More than 40 chemicals were evaluated in the field on more than 26 plant species as pre- and postemergence treatments using the logarithmic sprayer.

Corn, cotton, flax, lima beans, peas, sorghum, and soybeans were exceptionally tolerant to preemergence treatments with N-(3-trifluoromethyl-phenyl)-N',N'-dimethylurea at levels which resulted in good to excellent control of broadleaved and grassy weeds. While corn, cotton, oats, and sorghum were exceptionally tolerant to postemergence treatments of their herbicides.

2. Metabolism of Dalapon. In North Carolina, excised cotton, corn, and soybean root tips and hypocotyls (or mesocotyls) exhibited different patterns of uptake of dalapon. Corn, the most sensitive plant, accumulated the greatest amount of dalapon, while cotton, the most tolerant, contained the smallest amount. Different mechanisms of accumulation probably operate in each species.

3. Herbicide Persistence in Soils. A nine-year study in California indicates that neither monuron nor diuron applied as annual broadcast layby treatments in irrigated cotton accumulates in amounts toxic to cotton. In Mississippi and California research indicates that several herbicides, including diuron, linuron, trifluralin, prometryne, dimethyl 2,3,5,6-tetrachloroterephthalate (DCPA), and several newer herbicides, used at rates necessary for weed control may injure one or more susceptible crops planted during periods up to one year after application.

4. Phytotoxicity of DSMA Residues. Rice was injured when grown in soil containing 10 ppmw or disodium methanearsonate (DSMA) and appears to be much more susceptible than other crops such as soybeans and cotton. Crop injury from DSMA in the soil appears associated with soil phosphorus and soil texture.

5. Herbicide Residues. Cotton herbicide residues remaining in the soil have injured vegetables grown in rotation at Weslaco, Texas. Research to find nonresidual herbicides for cotton has shown that incorporated, pre-emergence applications performed better than surface applications of trifluralin, DCPA, diuron, prometryne, and norea in cotton. Trifluralin and DCPA were outstanding. The herbicides failed to penetrate below 3 inches in the fine sandy loam, but all were markedly deactivated after 3 months.

B. Physiology, Biochemistry and Ecology

1. Prometryne in Cotton. Supposedly glandless cotton plants (Empire variety) were found to accumulate C^{14} -prometryne along the stems and petioles in sites which closely resemble the glands of glanded plants in studies in North Carolina. Radioactive materials, insoluble in water or organic solvents, present in cotton plants treated with C^{14} -prometryne were found to be associated predominantly with pectin and hemicellulose.

2. Cotton Response to Trifluralin. Topical applications of trifluralin in California to 4-inch cotton caused shortening of internodes, but lateral fruiting branches developing after application were normal. Incorporated preplanting trifluralin inhibited lateral rooting of cotton. This, together with adverse weather, resulted in occasional stand reductions and reduced yield in Mississippi.

3. Fungicide Reduces Herbicide Injury. Research in Mississippi indicated that use of a recommended hopper box fungicide at planting reduced the injury to cotton by diuron applied preemergence.

C. Weed Control

1. New Herbicides. New herbicides showing promise for control of annual weeds in cotton or soybeans included N-(3-trifluoromethylphenyl)-N', N'-dimethylurea, 2-chloro-N-isopropylacetanilide, 3,4-dichlorobenzyl N-methylcarbamate, and N-(beta-O,O-diisopropylthiophosphorylethyl)benzene sulfonamide.

2. Preplanting and Preemergence Herbicides. Trifluralin, DCPA, norea, diuron, and prometryne were the outstanding preplanting or preemergence herbicides for control of annual weeds in cotton in Arizona, California, and Mississippi. Incorporation of trifluralin and DCPA appears desirable in most locations. Incorporation of the other material produced desirable or undesirable results according to local conditions and methods of use.

3. Postemergence Herbicides. In Arizona, California, and Mississippi, early-season postemergence applications of DSMA, DSMA plus diuron, naphtha, diuron, linuron, and various combinations of these have good control of many annual weeds, nutsedge, and young Johnsongrass. Other materials were less effective or caused excessive injury to the cotton.

4. Combination Practices. In Mississippi, triband weed control, involving splitband applications of EPTC at planting and preemergence diuron; and various combinations of DSMA, diuron, naphtha, and flame applied post-emergence resulted in normal yields of cotton and excellent season-long control of annual weeds and nutsedge. In Arizona, preplant applications of incorporated trifluralin combined with postemergence diuron gave season-long control of annual weeds. Similar combinations were also more effective than single component practices in California.

5. Method of Herbicide Application. Topical sprays of DSMA, diuron, prometryne, and DSMA plus 3',4'-dichloro-2-methylacrylanilide were only slightly more effective than directed sprays for control of weeds, and caused substantially more injury to the crop in Mississippi. Late-season applications of DCPA or trifluralin incorporated in the soil between rows, or combinations of EPTC plus diuron and EPTC plus trifluralin applied subsurface in the row middles gave better control of weeds than conventional applications of diuron to the soil surface in several States.

6. Granular Herbicides. CIPC and prometryne granules appear to offer some resistance to loss of the herbicides by volatility in Mississippi.

7. Herbicides in Irrigation Water. 2,3,6-trichlorophenylacetic acid at .27 to 1.35 lb/A and picloram at 1 oz./A applied in the irrigation water injured cotton and resulted in slight to moderate yield reductions in Arizona.

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NEMATODE IDENTIFICATION, PHYSIOLOGY, AND CONTROL
Crops Research Division, ARS

Problem. Plant-parasitic nematodes attack most crops in the United States, causing a loss estimated at more than 370 million dollars a year for only 18 of the crops grown in the United States. Most plant-parasitic nematodes infect roots and other underground parts of plants; but some very important species attack bulbs, stems, leaves, and flowers. Damage initiated by nematodes is often extended by bacteria, fungi, and viruses. Control methods include use of nematocides, crop rotations, cultural practices, resistant varieties, and biological agents. Damage can be greatly reduced by use of varieties resistant to nematodes, but only a relatively few resistant varieties have been developed. Development of resistant varieties is a time-consuming task and does not completely protect the crop because multiple nematode resistance is difficult to attain and is lacking in all varieties thus far developed. Crop rotations have been devised to reduce some of our more important nematode problems, but rotations rarely fit modern management practices or are uneconomical. While naturally occurring biological agents undoubtedly have a great influence on nematode populations, manipulation and use of these principles for economic control of nematodes is not yet practical. Great advances have been made in chemical control, but use of nematocides on many crops is not economically feasible. More effective and cheaper nematocides and improved methods of application are needed. Basic research is needed to determine the mechanism of nematocide action and on their effects on the soil and plant. Additional research is required to improve all methods of nematode control for annual crop plants and to develop methods of controlling nematodes on perennial crops in orchards, groves, vineyards, and nurseries. To aid in this research, expanded basic studies of taxonomy, pathology, physiology, nature of resistance, genetics, and the ecology of nematodes are needed.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term, continuing program of basic and applied research on various phases of nematology which contributes information of value to nematode control. In the past few years, as State nematology programs have developed, there has been increased emphasis on basic research by the Department. Fundamental research on nematode taxonomy, pathology, ecology, and physiology is located at Beltsville, Maryland; and 13 field stations combine applied and basic research approaches to commodity problems. Research of nematodes affecting cotton is located at Auburn, Alabama; Tempe, Arizona; Tifton, Georgia; Baton Rouge, Louisiana; Lubbock, and Weslaco, Texas, and Shafter, California. The work is in cooperation with respective State Agricultural Experiment Stations.

Contract research is in progress at the University of Florida on the predacious soil organisms attacking plant-parasitic nematodes; at the University of Maryland on the chemical nature of plant resistance to nematodes; at the University of California, Riverside, on the effect of soil amendments and nematocides on biological control processes of plant nematodes.

The Federal scientific effort devoted to nematology research in FY 1964 totaled 27.3 man-years including 2.3 man-years per year of contract research. Of this 13.0 were devoted to basic research on nematodes and 2.8 to cotton.

PROGRAM OF STATE EXPERIMENT STATIONS

Nematology research programs are actively pursued in 47 States and Puerto Rico. Collectively, this well-organized research program is supported not only by the institutions involved, but also by such agencies as the National Science Foundation, National Institutes of Health, private institutes, foundations, and industry. Fundamental investigations in nematology continue to receive major emphasis by State scientists. Basic studies on the specifics of virus transmission by nematodes are being further investigated. Pioneering studies on the physiology and biochemistry of nematode pathogenicity, reproduction, and nutrition are contributing much new knowledge. A number of scientists are determining the actual biochemical specifics of nematode resistance in plants. Several nematologists are pursuing basic studies on the cytology and genetics of nematode species, particularly for Heterodera and Meloidogyne. Also refined serological techniques for use in identification of nematode species and races are being investigated. Research on many fungi, bacteria, and viruses as biological control agents has been intensified. Use of cultural and management practices in controlling a wide range of nematode types is to be studied to determine the effects of environment, soil, and plants on survival, reproduction, and losses. Many projects are also designed to determine the mode of action of specific chemicals on nematodes, and to determine the retention of these chemicals in plants and in the environment. Several scientists are concerned with more applied facets of research, which are of immediate use by extension, industry, growers, and the public in general. These studies include the development of nematode-resistant varieties, the evaluation of nematocides, and the development of practical crop rotations and sanitary practices. Cooperation and coordination of some of these research areas are facilitated by four Regional Research Projects in nematology and makes possible a network of effective research activity. Other facets of nematology research are reviewed in the appropriate crop sections of this reprint.

The research effort summarized herein is 54.9 man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Basic Studies

Evaluation of Chemicals as Nematocides. Field evaluations of nematocides supplied by industry were tested at seven field locations on citrus, cotton, tobacco, vegetables, turf grasses, sugarbeets, and alfalfa. The most promising chemicals were 1) DD + methylisothiocyanate, 2) tetrachlorothiophane, 3) diethyl methylsulfinyl phenyl phosphorothioate, 4) dichlorophenyl methanesulfonate, 5) diethyl pryazinyl phosphorothioate, 6) diazon, 7) demeton, 8) phorate, 9) dichloropenes + chloropicrin + propargylbromide, 10) chloropicrin + methylisothiocyanate, and 11) several cadmium compounds. The insecticide phorate gave outstanding nematode control when applied to turf. Dichlorophenyl methanesulfonate performed well at several locations, but root-knot control under western irrigated conditions was the best that had ever been achieved with nematocides. Work was completed at Tifton, Georgia on evaluating wide-range soil sterilants such as SMDG and the mixture of DD + methylisothiocyanate as row treatments for control of nematodes, weeds, and soil fungi. Chemicals with similar properties will be evaluated for this purpose in the future. Twenty-six surfactants having bactericidal properties were evaluated as nematocides. Several gave fair control of nematodes.

B. Control

Control of nematodes by crop rotation was studied at four locations. Populations of the soybean-cyst nematode (Heterodera glycines) were greatly reduced in rotations of cotton and NC-55 soybean (nematode resistant) indicating the need for planting a nonhost crop or a resistant variety to prevent damage from the soybean-cyst nematode. At Alabama, rotations of cotton, corn, and peanuts indicated that the root-knot nematode (M. hapla) was increased by peanuts and suppressed by cotton and corn. The ring nematode (C. ornatum) increased on peanuts but was controlled by cotton and corn. Root-lesion nematodes (P. minyus) increased on corn but were reduced by cotton and peanuts. The stubby-root nematode (T. christiei) increased on cotton and corn but was controlled by peanuts. Corn and sod rotations at Tifton and Watkinsville, Georgia, indicated an increase of sting (B. longicaudatus), root-lesion (P. brachyurus), and dagger (X. americanum) nematodes on coastal bermudagrass, alfalfa, and fescue. In a cover crop rotation study at Tifton and Attapulgus, Georgia, Crotalaria and summer fallow controlled a greater variety of nematodes than other crops, whereas fallow, millet, and sudangrass greatly increased sting, root-lesion, stubby-root, and ring nematodes. Rotation studies with summer cover crops and coastal bermudagrass at Tifton, Georgia, showed that millet, beggarweed, and coastal bermudagrass increased all ectoparasitic nematodes. Crotalaria and marigolds (Tagetes minuta) controlled most ectoparasitic nematodes and root-knot (Meloidogyne spp.). Studies at

Salinas, California, indicate that summer fallow aids in controlling the sugarbeet nematode (H. schachtii). Additions of molasses and sugarcane filter press in the furrow increased activity of microorganisms antagonistic to plant nematodes and appeared to increase sugarcane yield, but the yield increase was not associated with nematode control. However, these soil amendments did increase populations of free-living, nonparasitic nematodes that might be competitive with the plant-parasitic forms.

Root-knot nematode problems of cotton in Arizona are increasing; this is attributed to the use of the Deltapine variety, which is highly susceptible to root-knot, with losses now estimated at 2 1/2 to 3 million dollars a year compared with about 1 million dollar losses when Acala cotton was grown in this area. On land lightly infected with root-knot nematodes, cotton yields were increased by about 1/2 bale of lint cotton by application of nematocides; on heavily infested land application of standard nematocides increased cotton yields by more than 1/2 bale. In Louisiana, control of light infestations of the reniform nematode (R. reniformis) and the root-knot nematode (M. incognita acrita) with nematocides increased seed cotton yields in two locations by about 200 pounds of seed cotton. Also, the incidence and severity of reniform nematode damage on cotton are increasing in the lower Rio Grande Valley, but control experiments have not been undertaken in this area. Furrow applications of nematocide, fungicide, and insecticide mixtures showed promise in controlling nematodes and soilborne diseases of cotton in tests at Louisiana and Alabama. The best treatments increased cotton yield by more than 50%. Twenty-five species of Gossypium cotton of worldwide origin were evaluated at Tempe, Arizona, for root-knot resistance. Four groups of diploid species and three groups of tetraploid species were evaluated. The only species that were highly resistant or immune to root-knot were G. klotzschianum and G. davidsonii (previously reported by A. L. Smith at Auburn University).

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COTTON INSECTS
Entomology Research Division, ARS

Problem. Insects are major deterrants to economical production of cotton and their control is a major cost factor in the production of the crop. Although present insecticide control measures for various cotton pests have been effective enough to keep growers in the cotton production business, they leave much to be desired from the standpoint of safety, efficiency, and undesirable residues. The development of resistance to certain insecticides in 20 cotton pests emphasizes the need for basic information on ways to solve or avoid the problem and to develop other methods of control that are more effective, economical and desirable. An imbalance of beneficial insect populations and hazards to fish and wildlife may result from insecticides now employed on cotton. More research on approaches to control such as sterile male or female techniques, repellents, cotton varieties resistant to insects, biological control agents, safer insecticides, more effective ways of applying them, and chemically induced plant resistance to insect attack is needed to develop improved methods of control. Effective methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. The boll weevil is gradually extending its range westward and may be adapting itself to an arid climate. A boll weevil found attacking cotton in northwestern Mexico and in Arizona is posing a threat to cotton production in New Mexico and California where it does not now occur. One of the basic difficulties in cotton insect control is the lack of knowledge of factors influencing insect abundance. Such knowledge could serve as a basis for advising growers when control measures for the various pests will or will not be required.

USDA AND COOPERATIVE PROGRAM

Research on cotton insects is conducted at field laboratories located at Florence, S. C.; State College, Miss. with satellites at Stoneville, Miss. and Tallulah, La.; Baton Rouge, La.; College Station, Tex.; Brownsville, Tex. with a satellite at Waco; and Tucson, Ariz. with a satellite at Tempe.

Various aspects of research being conducted are as follows: (1) studies of ecological factors which affect population dynamics, damage, distribution, life histories, survival and dispersal of various cotton pests in different areas; (2) basic research on the physiological processes and biochemical requirements in the normal metabolism of such insects as the boll weevil, bollworm, tobacco budworm, pink bollworm, cabbage looper, beet armyworm and salt-marsh caterpillar to develop improvements in procedures for mass rearing; (3) studies to determine the mode of action and fate of various chemicals in and on such insects as the bollworms and boll weevil and to determine the mechanisms by which the insects are able to develop resistance to insecticides; (4) studies to discover and develop more effective conventional and systemic insecticides and to improve methods of application

to increase their efficiency in controlling various cotton pests; (5) research to discover and develop methods of using pathogens or other biological agents to control the boll weevil, bollworm, tobacco budworm, cabbage looper and other cotton pests; (6) studies to discover and develop cotton varieties resistant to or tolerant of attacks of such pests as the bollworm, tobacco budworm, cabbage looper, pink bollworm, boll weevil, cotton fleahopper, cotton aphid and spider mites; (7) research to develop the sterile-insect technique and procedures for using it alone or in combination with other methods for controlling or eradicating the boll weevil and pink bollworm; (8) studies to develop practical methods of employing biologically active compounds, attractant, feeding stimulant, and repellent, of the cotton plant, and sex attractants for controlling cotton insects; and (9) development or improvement of equipment for insect control such as stalk shredders, machines to collect and destroy boll weevil infested cotton squares, gin and oil mill equipment, light traps, and ultrasonic and electronic equipment.

The research is conducted in cooperation with the Agricultural Experiment Stations of South Carolina, Mississippi, Louisiana, Texas and Arizona and with the Plant Pest Control, Crops Research, Soil and Water Conservation, and Agricultural Engineering Research Divisions. Research is also supported by grants, contracts or cooperative agreements with Texas, Mississippi and California Agricultural Experiment Stations and the Southern Research Institute.

The Federal Scientific effort devoted to cotton insects research totals 67.8 professional man years. Of this number 24 are devoted to basic biology, physiology and nutrition; 18 to insecticidal and cultural control; 5 to biological control; 12 to insect sterility, attractants and other new approaches to control; 1 to evaluation of equipment for detection and control; 4 to varietal evaluation for insect resistance; 0.8 to insecticide residue determinations; and 3 to program leadership:

In addition Federal support for 1.8 man-years of research in this area is provided in contracts and grants. Of this total 0.9 is devoted to basic biology, physiology and nutrition; 0.6 to biological control; and 0.3 to insect sterility attractants and other new approaches to control.

PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research programs on cotton insects are conducted by the major cotton-producing states. Information is being obtained on the ecological factors responsible for rapid population increases of pest insects as a basis for accurate forecasting of destructive outbreaks. Variations in insect numbers and behavior through hibernation, spring emergence, summer development and diapause are being determined. Laboratory studies are under way to learn what factors are responsible for initiation of diapause in the boll weevil, pink bollworm and cotton bollworm. Emphasis is being

placed on the influence of light, nutrition and temperature. Other studies are concerned with the influence of chemosterilants and radiation on reproductive physiology. Laboratory rearing techniques, using artificial lights, are being developed to provide insects for year-round study, and to determine the effects of varying concentrations of nutrients in the diet.

Biological information is being assembled on rates and characterization of developmental stages, rate of egg deposition, mating habits, longevity and mortality.

Cultural control studies include the influence of varying fertilizer levels on infestation size, the benefits obtained from crop residue destruction in the fall, and the development of varietal resistance. Research in the latter area consists of screening introduced plants for resistance, crossing them and selecting progeny which exhibit useful traits. Biological, physiological and chemical studies are conducted to determine the factors responsible for resistance.

Chemical control studies include the evaluation of new materials with particular emphasis on systemic insecticides. Research includes basic mode of action studies in insects and the metabolism of systemic insecticides in the cotton plant. Various methods of application are being evaluated for field use.

The total State scientific effort devoted to cotton insect research is 53.8 professional man years.

PROGRESS--USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Boll Weevil. Two stub cotton fields in Pinal and Yuma counties, Arizona, were found infested in June, 1964. The infestation became heavy by the end of August. The yield loss was estimated to be $1\frac{1}{4}$ bales in the Pinal County field and $1\frac{1}{2}$ bales per acre in the Yuma County field.

Crosses of F_1 and F_2 progeny from Caborca, Mexico weevil and Tucson thurberia weevil crosses produced progeny in studies at Tucson, Arizona. Caborca by thurberia females crosses with thurberia by Caborca males laid an egg from which an adult was reared. Two females from crosses of F_2 progeny laid viable eggs. These results indicate that the weevils in Caborca, Mexico cotton are the same species as the thurberia weevils in Tucson, Ariz.

In laboratory studies at Tucson, Arizona hybrid females from crosses of Caborca, Sonora and Tucson thurberia weevils produced viable eggs for as long as 3 months after mating. Four thurberia-cotton hybrid females which had been mated with male thurberia weevils produced viable eggs 7, 13, 52, and 95 days after the removal of the male, and six cotton-thurberia hybrid females laid fertile eggs for 13, 15, 25, 38, 42, and 96 days after separation from the males. In these tests the laying of viable eggs was limited only by the insects' longevity.

High boll weevil survival in old bolls was indicated for a Yuma County, Arizona field that grew stub cotton in 1964. The stalks had been destroyed with a shredder. Boll inspections made on February 9, 1965 in this field showed an average of 1254 live adult weevils per acre. Boll weevils emerging from ground trash in hibernation cages on March 15 in Pima and Pinal Counties, Arizona indicated that they are able to overwinter outside the boll from one crop year to the next. Thurberia weevils have been known to overwinter only in bolls.

A live female thurberia weevil was removed from a thurberia boll which had been held in storage for 17 months at State College, Miss. She lived for two months thereafter and laid 151 eggs.

Boll weevil survival in the spring of 1965 was higher than in 1964 in all areas. Spring woods-trash examinations for hibernating boll weevils were made in central Texas, northeast Louisiana, Delta and Hill sections of Mississippi and in three areas in the Carolinas. Comparative survival since 1960 in the various areas was as follows:

<u>Area</u>	<u>Weevils Per Acre</u>				
	<u>1961</u>	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>
Central Texas	1516	1361	452	97	4925
Northeast Louisiana	2193	2233	121	1049	3052
Mississippi	1246	1132	13	289	995
South Central South Carolina	376	1667	914	753	1855
Coastal Plains, N.C. & S.C.	1129	3654	1560	2742	10164
North Central North Carolina	430	968	161	107	1371

Boll weevil survival in 1965 was greater than the previous 4 years except in Mississippi where survival was slightly higher in 1961 and 1962. Survival in the coastal plains of the Carolinas was especially high. At Florence the number surviving was greater than in any year since records were made beginning in 1938.

At Tucson, one boll weevil emerged in the spring of 1965 from 27 gallons of green bolls collected in November, 1964 and installed on the soil surface in hibernation cages. Three weevils emerged from 21 gallons of green bolls installed in cages 6 inches above the ground on screens. Two weevils emerged from 100 pounds of bolls which were collected in early March from standing stalks in 3 fields in the area and installed in 6 hibernation cages. However, at Florence, S. C., boll weevils in green cotton bolls when the plants were killed by freezing temperatures failed to survive the winter. The infested bolls were held in the insectary, on the soil surface, above the soil surface, and on standing stalks in the field.

Egg deposition after October 1 does not contribute to the overwintering boll weevil population at State College, Mississippi. In this study of the fall biology of the boll weevil, eggs laid after October 1 did not contribute to the overwintering population. Eggs deposited during early to mid-September produced adults which emerged throughout October and early November.

The Texas A & M strain of boll weevils used in the mass rearing program at the State College, Mississippi laboratory appears to be non-diapausing. In laboratory experiments 11-hour photoperiod in larval and pupal stages, boll feeding in adult stage, limited number of squares made available in adult stage, and low night temperatures in adult stage did not induce diapause in this strain of weevils. A Mississippi wild strain held under identical conditions developed diapause.

Pink adult weevils were reared on larval diet containing dye at State College, Miss. The adults retained color for 8 weeks and females laid pink eggs. A calco oil red was the best of several dyes tested.

The boll weevil synthetic diet was modified at Florence, S. C. Additional tests have shown that a reduced amount of methyl parasept and potassium sorbate can be used to reduce contamination in adult laboratory boll weevil diets. This reduced amount is effective for at least 24 hours and does not significantly reduce egg production, hatch, or yields of adults.

In replicated laboratory tests at Florence, S. C. boll weevils oviposited at a higher rate on the synthetic diet containing egg albumin than on the diet containing cotton squares.

The pH of the mid-gut of boll weevil larvae was determined at State College, Miss. from larvae immediately after they were removed from artificial diet and from those starved 2 to 4 hours. The mid-gut was divided into the anterior (crop) and posterior regions for the analyses. The crop region had pH of about 5.8-6.1, and the posterior portion 7.1-7.6.

In studies at State College, Miss. free amino acids found in boll weevil pupae were cysteic, taurine, aspartic, threonine, serine, glutamic, proline, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, aminoisobutyric, lysine, histidine and arginine.

Physiological disposition of C^{14} tepa in the boll weevil was determined in studies at State College, Miss. Tepa has a biological half-life of 6 hours, is preferentially picked up by the foregut and gonads, is poorly absorbed through the integument and reaches its peak in the blood of the boll weevil in 90-100 minutes.

In studies at Baton Rouge, La. acetate-1- C^{14} injected into adult boll weevils undergoes immediate oxidative metabolism with the subsequent release of $C^{14}O_2$. Maximum $C^{14}O_2$ production is reached one hour after injection at which point about 25% of the injected acetate has been converted to CO_2 . Thereafter the release rate declines steadily. By 12 hours, 50% of the injected C^{14} has appeared as respiratory $C^{14}O_2$.

Boll weevil larvae synthesized long chain fatty acids from isotopically labeled acetate in their diet in studies at Baton Rouge, La. Oleic acid was the principal acid synthesized along with lesser amounts of palmitic, palmitoleic, stearic, and linolenic. Like the adult, the larvae does not synthesize linoleic acid. The amounts synthesized and labeling pattern were almost identical when C^{14} -1- and C^{14} -2-acetate were used as the precursors.

In studies at Baton Rouge, La. the boll weevil absorbed some fatty acids in its diet and stored them unchanged but modified the remainder to form other types of fatty acids. Labeled palmitic acid may be changed to palmitoleic by desaturation, or its chain may be elongated by two carbon atoms to stearic, which in turn may be desaturated to oleic. However, if labeled stearic acid is placed in the diet, it is absorbed unchanged or desaturated to oleic, and very little is shortened to form palmitic acid. If labeled oleic is used, it is absorbed primarily as oleic and neither the saturation or shortening pathways operate to any appreciable extent. The boll weevil larva cannot convert closely related dietary fatty acids to linoleic acid. Very little labeling of the linoleic fraction is found in body fat from weevils fed on tagged stearic and oleic acids. The slight counts in linoleic acid can be due to carryover from the highly radioactive oleic acid fraction.

In studies at Baton Rouge, La. diapausing boll weevils contained more total sterols than reproducing weevils. The greatest difference occurred in the sterol ester fraction, especially in the females. Two week-old diapausing females contained an average of 58 micrograms of sterol, over one-half of which was esterified. It is possible that this relatively large amount of sterol ester could contribute to the observed tolerance of diapausing weevils to chlorinated hydrocarbon insecticides.

At Baton Rouge, La. analyses of feces from weevils fed a diet containing C^{14} -cholesterol showed large amounts of unidentified polar steroids. The percentage of the total radioactivity present in the polar fraction ranged from 36 to 53%. Thus, it appeared that the boll weevil metabolized a substantial portion of its sterol before it was excreted. In contrast, the sterols in the eggs were almost entirely in the free sterol and sterol ester forms with only a trace of polar steroids.

In studies at Baton Rouge, La. crude extractable lipids accounted for almost 11% of the wet weight of 10-day-old adult boll weevils fed cellulose cotton moistened with 20% sucrose. If the boll weevil is unable to digest cellulose, these results indicate that sucrose is converted to lipid in the weevil and supports the theory that the higher titer of sugars in bolls than in squares is responsible for the accumulation of glycogen and triglycerides in boll-fed weevils.

Trehalose and glucose levels were determined in eggs and pupae of boll weevil at Baton Rouge, La. Both trehalose and glucose were present in the pupae but the titer of trehalose was only slightly higher than that of glucose. During the pupal period the levels of trehalose and glucose decreased from about 90 to 100 micrograms to about 30 to 45 micrograms per insect. Boll weevil eggs contained both trehalose and glucose, but the quantity of trehalose (2.78% of the dry weight) was considerably greater than the quantity of glucose (about 0.25% of the dry weight).

The rate of elimination of sterols by adult boll weevils was studied with C^{14} -tagged cholesterol at Baton Rouge, La. Weevils reared from larval diet containing 4- C^{14} cholesterol were sacrificed after feeding on untagged adult diet for 0, 1, 2, and 3 weeks. At the end of 3 weeks, the weevils had lost 70 to 80% of the original radioactivity. The females esterified the cholesterol a little more rapidly and lost slightly more radio-activity than the males.

Mutant strains of boll weevils were used to determine mating and reproduction patterns of females in studies at State College, Miss. Experiments showed that sperm mixing takes place when a female is mated with two different males but the second mating produced most of the progeny.

An all black strain of boll weevils has been developed at Florence, S. C. A small colony of these weevils is being maintained in the laboratory for use in future field studies.

Cholinesterase activity of boll weevils fed chronic sublethal or lethal doses of Bidrin was determined in studies at College Station, Texas. Adult boll weevils fed chronic doses of Bidrin had an initial cholinesterase decline and then a recovery to near normal. This indicates a secondary cause of death (other than ChE inhibition) in insects treated with organophosphorus insecticides or that only a small fraction of the total cholinesterase at a vital site is directly associated with death.

Boll weevil susceptibility to toxaphene is affected by lipid composition of the diet. Additional tests confirmed that weevils reared on diets containing a mixture of cottonseed-linseed oils (1:1) were less susceptible to toxaphene than those fed on a diet containing either cottonseed or linseed oils alone.

A strain of boll weevils resistant to chlorinated hydrocarbon insecticides reared on a fat-deficient diet in the laboratory at Baton Rouge continued to be highly resistant to endrin. There was a further increase in the resistance level of weevils reared on this diet when triolein was added in amounts as low as 50 mg per 100 g of diet.

In studies at Baton Rouge, La. the molecular weight of boll weevil glycogen extracted from larvae with cold water was much higher than that extracted with trichloroacetic acid. The sedimentation curves from the Spinco Model E ultracentrifuge showed two regions of different molecular weight.

The lower molecular weight component appeared at 150-200 svedbergs and the higher molecular weight material appeared at 900-1200 svedbergs. When larval glycogen was extracted with trichloroacetic the higher molecular weight component was completely destroyed, and the quantity of the lower molecular weight was increased.

In studies at Baton Rouge, La. the boll weevil synthesized long chain fatty acids from glucose-1- C^{14} in its larval diet. Palmitic and oleic acids accounted for nearly 70% of the C^{14} incorporated as fatty acid. The labelling pattern was quite similar to that obtained when the larvae are reared on a diet containing C^{14} acetate.

In studies at Baton Rouge, La. triglycerides, the dominant lipid constituents, made up 70% by weight of the lipid matter in boll weevil egg yolk. Sterol esters and sterols accounted for about 12% of the lipids, and free fatty acids for about 6%. The egg lipids were fractionated by a two-phase column chromatographic technique, and each fraction was checked by TLC. Triglyceride fatty acids of the boll weevil egg have a different spectrum than those of body fat. Linoleic acid (along with palmitic) replaces oleic as one of the two largest components. The free fatty acid fraction of eggs is somewhat similar to triglycerides but contains a larger titer of short chain components and lesser amounts of palmitic and linoleic acids.

In studies at Baton Rouge, La. the sugar content of the thurberi boll was found to be slightly lower than that of the cotton boll. Sugars account for about 10% of the dry weight of the thurberi boll. The two main sugars are glucose and fructose. The titer of sugars is higher in the larger bolls. The high sugar level is probably a very important

factor leading to the accumulation of carbohydrate and lipid reserves which probably enables the thurberia weevil to survive the winter in the thurberi boll.

In studies at Baton Rouge, La. weevils in diapause utilized palmitic and oleic acids at an even rate, but reproducing adults used more oleic acid than palmitic acid. The oleic:palmitic ratio remained unchanged at about 1.72 in weevils in diapause for 6 months, whereas in reproducing adults it dropped to 1.33 indicating a relative and selective decrease in oleic acid.

Boll weevil egg production was reduced at Baton Rouge, La. unless linoleic acid was available during larval stage. A fatty acid deficiency during the larval stage of either sex reduced the numbers of eggs produced. The larvae needed only very small amounts of polyunsaturated fatty acids. Linoleic and linolenic acids carried over from the parent generation through the egg satisfied the essential fatty acid requirements of the larvae. Although weevils could synthesize a large amount of oleic acid, they still laid more eggs in diet containing triolein as the only source of fatty acids. Gas chromatographic analyses showed that adults maintained on a fat-deficient diet contained significant amounts of linoleic acid. Some synthesis of this acid was indicated, since the trace amounts found in the larval diet were present at a much lower concentration. It was not possible to demonstrate a dietary requirement for vitamin E. Weevils maintained for three generations on diets containing no added vitamin E continued to lay large numbers of eggs.

In studies at State College, Miss. no linkage was found between two previously described genetic markers in the boll weevil. F_2 data indicated no linkage between the eye marker designated pearl, and the body marker, ebony.

Ground and aerial application of a blue enamel to cotton marked up to 38% of the boll weevil population in State College, Miss. and Tallulah, La. Yellow was inferior to the blue and the airplane applications appeared to be superior to ground sprayer applications. This technique should be of value in a number of boll weevil field studies.

A more efficient method of implanting eggs on larval media was developed at State College, Miss. Boll weevil eggs were suspended in a solution of 20 g. sucrose, 2 g. cornstarch and 100 g. water. The suspension was sprayed onto the roughened surface of the larval media.

In tests at State College, Miss. boll weevil eggs were not adversely affected by saturated salt solutions and strong acids. Eggs soaked over 72 hours in saturated copper sulfate and other salts hatched normally. Fifty percent phosphoric acid, 40% sulfuric acid and 20% nitric acid for 72 hours failed to destroy the eggs. Organic acids were toxic at very low concentrations. Sorbic acid was over 200 times as toxic to the eggs as potassium sorbate.

Metabolism studies of SD-9129-P³² in cotton plants at College Station, Texas indicated a metabolic route similar to that of Bidrin. An unknown metabolite in aged SD-9129 residues appears very similar to the Bidrin unknown. There is evidence that hydroxy-methyl Bidrin is a precursor to the Bidrin unknown.

The systemic activity of Di-Syston-P³² was determined in studies at College Station, Texas. Soil type influenced uptake of Di-Syston by cotton plants when the toxicant was applied in the soil. Much larger amounts of Di-Syston were recovered from plants growing in light soil than in heavy soil. Seed treatment tests indicated that larger amounts of Di-Syston were taken up by plants grown from acid delinted seed than from mechanically delinted seed.

Studies at College Station, Texas showed that Shell SD-9129 was translocated to nectar in cotton plants. In tests with SD-9129-P³² applied to cotton plants, significant quantities of the original compound was recovered in the nectar.

2. Bollworms. In 1964 studies of Heliothis spp. on cotton at Brownsville, Tex. showed H. virescens had 4 population peaks while H. zea had only two. Highest populations of H. zea were in the first peak (June 5-12) while that of H. virescens was in the last peak (August 7-14). The first peak of H. zea seems to be related to corn maturity. At Waco, Tex. only 7.4% of larvae collected on cotton during the season were tobacco budworms. This compares with 46% in 1963. At Stoneville, Miss., 10.5% of the larvae collected on cotton during the season were tobacco budworms, ranging from 35.5% in June to 4.5% in September. Eight percent of bollworm larvae collected on cotton at Tallulah, La. were tobacco budworms.

Heliothis virescens was collected on Indian paintbrush at Waco, Texas. Determinations of 222 bollworm larvae collected from 6 different early-season host plants during April and May, 1965, showed that 215 were H. zea (Boddie) and 7 were H. virescens (F.). All of the H. virescens were collected on Indian paintbrush. Although only two tobacco budworm moths were collected in the light trap, 90% of the larvae collected on cotton in June were determined as the tobacco budworm.

The tobacco budworm was the predominant Heliothis sp. on cotton early in the season at Stoneville, Mississippi. Eggs were collected in the field and larvae reared from them. Over 60% were tobacco budworms, 30% bollworms, and the remainder loopers and cutworms. Alfalfa appeared to be the preferred host of the bollworm early in the season. At Tallulah, Louisiana, the number of the 2 species of cotton was about the same.

3. Pink bollworm. One hundred twenty-five live and 50 dead pink bollworm larvae were found in 5 pounds of bolls collected from standing stalks in March, 1965 near Waco, Texas. Survival and moth emergence from this material in May and June was heavy.

Studies at Brownsville, Texas show that pink bollworms may be disseminated in okra shipments. Fancy and choice graded okra, totaling 70 bushels, was obtained periodically from packing sheds in Cameron County during the period April 22-June 15 and caged outdoors for moth emergence. One pink bollworm moth emerged on May 17 from okra collected April 15.

4. Other Insects. Infestation of lygus bugs in cotton in the early fruiting stage reduced yield at first picking up to 50%. In field cage tests introductions of 1 tarnished plant bug adult per plant per week for 3 weeks just prior to or during early squaring stage reduced the yield of seed cotton at the first picking as much as 50% when compared with unfested cotton.

Incubation time required for lygus bug eggs held at different temperatures in the laboratory at Tucson, Arizona provided formula useful in predicting time of egg hatch. The duration of the egg stage of Lygus hesperus at seven different temperatures suggested that 10° C. lies below the developmental threshold and that 40° C. lies above the limit at which hatching can occur. The data were used to calculate a regression equation which was converted into a formula $y = \frac{1000}{-77 + 8.06 X}$.

In studies at Tucson, Arizona salt-marsh caterpillar moths deprived of water or food laid a higher percentage of fertile eggs than fed moths. Moths fed 5 percent sugar solution laid an average of 1,111.5 eggs per mating pair, those fed distilled water 776.7, and those given no food or water 437.5. Comparative fertility of eggs laid by moths fed only water, those fed 5% sugar solution, and those unfed was 20.7%, 42.4% and 65.3%, respectively.

Lygus hesperus is predominant plant bug species in the spring in Arizona. Sweep net sampling of 33 alfalfa fields at bi-weekly intervals from April 20 to May 26, 1965, in the Yuma to Phoenix area totaled 3449 Lygus hesperus, 492 L. elisus and 36 L. lineolaris. Numbers in the above area per net sweep were more than twice that of the St. David to Safford Area.

B. Insecticidal Control.

1. Boll Weevil. The effectiveness of technical malathion applied at rates of 9.0, 9.6 and 12.8 fluid ounces per acre, 11.0, 11.7 and 15.7 ounces by weight, respectively, was evaluated against boll weevils near Afton, Dickens County, Tex. When weevils were caged on plants immediately after treatment, kills after 24 and 48 hours in the plot treated with 12.8 fluid ounces in 75 foot swaths were 98 and 100%. In the plot treated with 9.6 fluid ounces in 100 foot swaths, kills after 24, 48, and 96 hours were 68, 82, and 100%. In another test kills after 24 and 48 hours in a plot treated with 9.6 fluid ounces in 100 foot swaths were 82 and 98%. In a plot treated with 9 ounces in 75-foot swaths kills were 90 and 100%.

A replicated test was conducted at Tallulah, La. in which 16, 12, and 8 fluid ounces of technical malathion, 20, 15, and 10 ounces by weight, respectively, were compared with methyl parathion applied at 0.25 to 0.5 pound per acre in an emulsion. Infestation records indicated that there was no appreciable difference in control obtained with the various dosages of malathion, and control obtained with them compared favorably with that obtained with methyl parathion.

Malathion diapause treatments reduced overwintering boll weevil populations in Sonora, Mexico. Ground trash examinations in January showed that treatments of 10 and 16 fluid ounces of technical malathion per acre reduced populations by 60 and 90 percent, respectively, compared with populations in untreated fields at Caborca.

Overwintered boll weevil populations were reduced at Tallulah, Louisiana by ultra low volume applications of technical malathion in the fall. The average number of weevils per acre in June, 1965, in fields receiving various treatments last fall were as follows: malathion at 12 ounces 7 weevils; malathion at 16 ounces 5 weevils; methyl parathion at 0.5 pound per acre in a conventional spray 5 weevils; and untreated check 130 weevils per acre.

From studies at State College, Miss. it is hypothesized that surfactants are partially responsible for formulated malathion being less effective than the undiluted technical material. In a project to investigate the influence of surfactant structure and concentration on toxicity of malathion, plans to topically apply undiluted technical insecticides have been cancelled. Volumes of 0.0008 and 0.000,05 microliters of undiluted technical malathion and methyl parathion would produce 50% mortality if applied topically to the boll weevil. Volumes of less than 0.005 microliters can not be delivered reproducibly with present equipment.

Boll weevil populations did not reach damaging numbers until the second field generation in a Carroll County, Miss., diapause control experiment. Fall treatments in 1963 consisted of six applications of methyl parathion spray at 0.5 lb. per acre at 4- or 5-day intervals, plus defoliation and three selected follow-up treatments. Overwintered weevils in 1964 were estimated at 4.3, 2.7 and 26.0 per acre in the three diapause control treated fields. In two fields where diapausing weevils were not controlled, populations were estimated at 13 and 52 per acre prior to application of early-season insecticide treatments. Boll weevil control was not needed in the fall-treated fields until August 12, 1964.

In tests at Florence, S. C. in 1964 a granular formulation of candidate systemic insecticide, Union Carbide UC-21149 was effective against boll weevils at high rates. When UC-21149 was applied to cotton as a side-dressing at rates of up to 32 pounds per acre, it gave significant mortality of boll weevil adults feeding on squares and of boll weevil larvae

developing in squares and bolls. When applied just before cotton plants began to square, UC-21149 at 6.8 pounds per acre caused significant mortality of adults feeding on foliage and squares, and larvae developing inside squares for at least 3 weeks.

At College Station, Texas cotton stem and soil treatments with systemic insecticides were effective in greenhouse tests against boll weevils. In stem treatment tests Union Carbide UC-21149 and American Cyanamid CL-47031 were the most effective compounds. In soil treatment tests Union Carbide UC-21149 was the most active compound but it caused considerable phytotoxicity. Union Carbide UC-21149 applied to the soil was found in leaves, squares and square bracts of cotton plants grown in it. Boll weevil bioassay of various parts of cotton plants grown in the greenhouse in soil containing UC-21149 showed that the highest concentrations of the toxicant were in the leaves with significant amounts in the squares and square bracts. Candidate systemic insecticide, American Cyanamid CL-47031, applied as a stem treatment showed promise against boll weevils. The insecticide applied with a tractor mounted brush applicator gave better control than when it was applied with a lateral spray applicator.

A standard test procedure has been developed at State College, Miss. in which 0.007 to 0.056 microliter doses are applied topically to the adult boll weevil for screening candidate insecticides. Of sixteen compounds screened six had LD-50's between malathion and methyl parathion and the remaining ten had LD-50's greater than 1 microgram per weevil.

In small plot replicated tests at Stoneville, Miss. in 1964, 1 pound-per-acre dosages of General Chemical GC-9160, Mobil MC-A-600, EPN, Geigy 12968 and 13005, and Bayer 44646, and 0.5-pound dosages of Niagara 10242 and Shell SD-9129 were as effective as such standard materials as 0.25 pound of Guthion plus 1.0 pound of DDT or 2 pounds of toxaphene plus 1.0 pound of DDT per acre. A mixture of 1.5 pounds of carbaryl plus 0.75 pound of UC 10854 gave better control than carbaryl at 2.0 pounds per acre. A mixture of 2 pounds of toxaphene plus 1.0 pound of DDT plus 0.25 pound of dioxathion was more effective than the mixture without dioxathion.

2. Bollworms. Several insecticides were effective against bollworms in field tests. In one experiment at Waco, Tex. there was no difference in control obtained with the following materials: Bayer 44646 at 2.0 pounds; Shell SD-9129 at 0.5 and 1.0 pound; Shell SD-8447 at 1.0 pound; and toxaphene at 2 pounds plus DDT at 1.0 lb. per acre. In another experiment Mobil MC-A-600 at 2 pounds and a polyhedra virus at 100 diseased larvae per acre gave control of a light bollworm infestation equal to carbaryl at 2.0 pounds.

At Brownsville, Tex., Shell SD-9129 at 0.8 pound and Bayer 44646 at 2 pounds per acre gave better control of a heavy infestation of bollworms and tobacco budworms than 2 pounds of toxaphene plus 1 pound of DDT per acre

and produced higher yields. At Tucson, Ariz. Geigy GS-13005 and GS-12968 were less effective than toxaphene plus DDT, Shell SD-9129 was effective. Carbaryl failed to give adequate control. At Stoneville, Miss., 1 pound acre dosages of Bayer-44646, Geigy 13005 and 12968, Stauffer B-10046 and AC-52160 and an 0.4 pound dosage of Shell SD-9129 were as effective as such standards as carbaryl at 2 pounds and toxaphene at 2 pounds plus DDT at 1.0 pound per acre.

Recommended compounds were effective against bollworm moths in cage tests at Florence, S. C. Cotton plants grown in pots in the greenhouse were treated with carbaryl at 2 and 1.5 pounds, DDT at 1.5 pound and methyl parathion at 1.0 pound per acre. The plants were covered with screen cages and moths were introduced 1 and 24 hours after treatment. All insecticides were significantly better than the check 1 and 24 hours after treatment. Carbaryl at 2 pounds was better than all other insecticides and at 1.5 pound it was better than DDT or methyl parathion. DDT was better than methyl parathion.

In laboratory tests bollworm larvae from Phoenix area were nearly three times more resistant to carbaryl than those from Tucson, Arizona. Results of topical applications, dosage-mortality tests, with 365 F₁ generation larvae from pupae collected in a field located in one of the heavily treated areas near Phoenix compared with 1140 F₁ generation larvae from Tucson showed that the Phoenix bollworms were 2.67 times more resistant to carbaryl than the larvae from Tucson.

In various tests at Florence, S. C., in 1964 granular formulations of the candidate systemic insecticide, UC-21149, were ineffective against bollworms. In one test the treated cotton had fewer squares than the untreated cotton. This was probably due to increased numbers of bollworm larvae on the treated cotton because of depleted predator population.

Bidrin, Shell SD-9129, and American Cyanamid CL-47031 showed promise as stem treatments for bollworm control at College Station, Tex. Newly hatched larvae were caged on terminals of individually treated plants growing in the field. Mortality records showed up to 80% control. Shell SD-9129 was the most effective compound.

3. Other Insects. At Waco, Tex. in 1964 UC-21149 applied at 1 pound per acre in a granular formulation in the furrow at planting gave better fleahopper control than granular phorate applied in like manner at rates of 0.3, 0.7, and 1.2 pounds or as a seed treatment at 0.21 pound per acre. There was earlier fruit set in the UC-21149 treatment because of the superior fleahopper control and it produced significantly higher yield than all other treatments.

Side-dress applications of American Cyanamid CL-47031 and phorate granules prevented infestations of the desert spider mite in a field experiment at Waco, Tex. in 1964. A bollworm infestation developed in an experiment conducted to compare different methods of applying systemic insecticides for cotton fleahopper control. The entire experiment received 7 applications of carbaryl at 2 pounds per acre between July 10 and August 8. Infestations of the desert spider mite in the plots that received side-dress applications of CL-47031 and phorate on June 2 remained light through the season.

Infestations did not build up to injurious levels until August in plots in which CL-47031 was applied as a stem treatment on June 9. Plots that were treated with toxaphene plus DDT on June 11 and the original check required treatment for spider mite control on July 24.

Systemic insecticide UC-21149 was effective against plant bugs in various tests in 1965. At Stoneville, Miss., in greenhouse and field cage tests UC-21149 was effective against the tarnished plant bug Lygus lineolaris for a longer period after planting than NIA-10242, GC-9506, phorate or Di-Syston. At Tucson, Ariz. in greenhouse tests UC-21149 at 2 pounds per acre in a granular formulation gave 93% kill of Lygus hesperus. NIA-1042 and phorate were ineffective at the same dosage.

New systemic insecticides show promise for thrips control of seedling cotton in field tests in 1965. At Stoneville, Miss. UC-21149 applied as a granular formulation at planting or sprayed on the seed gave outstanding control although control with NIA-10242 and GC-5306 was good. At Waco, Tex. NIA-10242 and phorate each at 1.1 pound and UC-21149 at 2, 1.3 and 0.6 pound per acre applied as granules in the furrow at planting gave good thrips control for 9 weeks. There was no difference among systemic insecticides but all of them were significantly better than the check. At Tallulah, La. thrips control with UC-21149 applied in a granular formulation in the furrow at 1 pound per acre was equal to that obtained with the same rate and application of phorate and Di-Syston.

Stem and side-dress treatments with systemic insecticides were effective in greenhouse tests against lygus bugs at College Station, Texas. Union Carbide UC-21149 was the best compound tested. It was effective for 20 to 30 days after treatment against nymphs and adults.

In field experiments at Waco, Tex. in 1965, SD-9129 at 0.25 and 0.5 pound per acre applied as a stem treatment and UC-21149 as a granule side-dress application at 2.18 pound per acre gave fleahopper control equal to that obtained with 1.0 pound of toxaphene plus 0.5 pound of DDT applied as a conventional spray.

UC-21149 at 2.0 and 1.3 pounds per acre applied as granular formulations in the seed furrow at planting gave good fleahopper control for 10 weeks after planting in field experiments at Waco, Tex. in 1965. On June 29, approximately 10 weeks after planting, the infestation per 100 terminals in the various in-furrow treatments was as follows: UC-21149 at 2.0, 1.3, and 0.6 pounds per acre, 2.8, 5.8, and 28.3 fleahoppers respectively; 1.1 pound of NIA-10242, 36.5; 1.1 pound of phorate, 46.8; and untreated check, 42.5. The longer effectiveness of the UC-21149 this year compared with that of 1964 is probably due in part to the small size of the plants which were stunted by excess moisture during May.

In various tests at Florence, S. C., in 1964 granular formulations of the candidate systemic insecticide, UC-21149, were effective against thrips, the cotton aphid and spider mites but they were ineffective against cabbage loopers.

Laboratory and limited field data at College Station, Tex. indicated that Azodrin and UC-21149 applied to cotton stems are effective against lygus bugs, fleahoppers, spider mites, and cotton aphids. The insecticides applied with a tractor mounted rotary brush applicator gave better insect control than when they were applied with a lateral spray applicator.

Several new insecticides were effective against tarnished plant bugs in field tests at Stoneville, Miss. in 1965. GC-6506, MC-A-600, Bayer 44646, GC-9160, GC-1300 S and SD-9129 applied as sprays in field tests all gave good control of this pest.

Residual effectiveness of trichlorfon against the cotton fleahopper was poor in field tests at Waco, Tex. in 1965. Three days after treatment, SD-9129 and Bidrin each at 0.1 pound per acre gave fleahopper control equal to that obtained with 1.5 pound of toxaphene plus 0.75 pound of DDT per acre. Control with trichlorfon at 0.5 pound was less effective and at 0.25 pound was poor.

Several candidate insecticides were promising against thrips applied as sprays in field tests. At Stoneville, Miss. GC-6506, SD-9129, GC-9160 and GS-13005 gave control comparable with that of the standard. At Waco, Bidrin SD-9129, Geigy 13005 each at 0.1 pound and Bayer 44646, MC-A-600 and carbaryl each at 0.5 pound per acre gave good initial thrips control with no difference among treatments. One week after treatment Bidrin and SD-9129 were more effective than all other insecticides except carbaryl.

Ultra low volume applications of malathion and methyl trithion were effective against thrips. Technical malathion applied at 1 pint (1.25 pound) per acre to 30 acres of cotton gave good control of thrips at Tempe, Ariz. It was more effective than dieldrin at 0.5 pound per acre in a total volume of 3 gallons of spray. At Waco, Tex. there was no difference in thrips control with malathion at 1/4 and 1/2 pint (5 and 10 ounces) and methyl trithion at

0.25 pound per acre and Guthion applied as a conventional spray at 0.25 pound per acre. All of the treatments reduced the thrips population significantly below that of the check. Ultra low volume malathion applied at 1/4 and 1/2 pint (5 and 10 ounces) per acre gave good control of a heavy thrips infestation at Tallulah, La.

Bayer 52553, Stauffer B-10228 and Upjohn U-20493 were highly effective at 0.25 pound per acre or less against adult lygus bugs in laboratory tests at Tucson, Ariz. In tests against fourth-instar salt-marsh caterpillar larvae General Chemicals GC-6506 and Virginia-Carolina VC 9-104 at 1 pound per acre gave mortalities of 83 and 87 percent, respectively, in 72 hours.

The toxicity of insecticides to bollworm predators was determined in laboratory tests at College Station, Tex. Insects were either treated topically or exposed to a treated surface. Results showed that trichlorfon, demeton and phosphamidon were less toxic than Bidrin and methyl parathion to Hippodamia convergens, Collaps balteatus, Chrysopa spp. and Orius spp.

Toxicity of several insecticides to the parasite Campoletis perdinctus was determined at Brownsville, Tex. Fifteen insecticides, all applied at 0.47 pound per acre, were compared for toxicity to C. perdinctus in laboratory tests. DDT and TDE did not cause mortality at this rate, but methyl trithion, carbaryl, and toxaphene-DDT gave mortalities of 29%, 60%, and 80%, respectively. All other treatments gave 100% mortality.

In the laboratory at State College, Miss. the boll weevil ectoparasite, Bracon mellitor Say, developed resistance to insecticides. In topical applications to 5 or more generations the parasite developed four fold resistance to DDT, Sevin, and methyl parathion and 8 fold resistance to toxaphene-DDT. No resistance developed when toxaphene was applied alone. Although resistance levels were relatively low, the studies to indicate that mechanisms for developing resistance to insecticides do occur in the species.

4. Pink Bollworm. The DDT-resistant laboratory pink bollworm culture which originated at Presidio has been reared through 20 generations at Brownsville. Adults were treated topically with DDT in acetone at 1 μ l of solution per moth at dosages of 7.5 and 10.0 μ g of DDT per moth. Mortality and therefore susceptibility increased considerably in the 20th generation compared with that of the 17th through 19th generations. Approximately 50 moths will start the 21st generation.

C. Biological Control

1. Boll Weevil. Boll weevils were infected with Mattesia grandis spores in field cage tests with a granular formulation containing the spores, agar, sugar and feeding stimulant at State College, Miss. Tests in 30"

x 30" x 30" cages failed to show differences in incidence of infection when formulations were prepared without sugar, feeding stimulant or both. A test in 6' x 7' x 24' cages designed to observe population reduction over 2 generations resulted in sufficient infection to produce some reduction, but it is not known if the degree of reduction was significant. Mattesia grandis and a microsporidian were produced in sufficient quantities for field tests by infecting boll weevil larvae at State College, Miss. A spore suspension was sprayed on larvae in diet plates. The yield of spores per insect was 2×10^6 (M. grandis) and 1.3×10^8 (microsporidian). With these methods the microsporidian could probably be mass produced at an economically feasible cost. More economical methods would have to be developed to produce M. grandis.

In October and November 1964 a high number of adult dead weevils found in bolls in a cotton field near State College, Miss. were killed by naturally occurring diseases. External fungal growth was evident on the weevils. Two types of fungi were produced after separation and incubation and over 60 bacterial cultures from internal content of the weevils. The majority of the bacterial isolates belonged to the Cloaca A or Serratia groups of Enterobacteriaceae. Representative cultures injected into adults did not produce mortality compared with 100% mortality with injected S. marcescens.

A nematode, Hexamermis sp., 2 3/8 inches long was recovered from a weevil at Tallulah, La. The nematode was dissected from an overwintered boll weevil collected on a greenhouse grown plant used as a trap near a hibernation site.

The parasite, Bracon mellitor, was reared successfully on boll weevil larvae developing on artificial medium in petri dishes in the laboratory at State College, Miss. Almost 100% of the weevil larvae were parasitized when a multi-perforated cotton leaf disk was placed over open larval cells. Molds proved to be a real problem and prevented most adult parasites from emerging.

In studies at State College, Miss. Bracon mellitor females laid an average of 7.5 eggs per day in the adult age span of 6 through 26 days. This average was quite consistent for the 5 females observed. The highest rate occurred on the 12th day when the females laid an average of 10.8 eggs.

Eight hundred and thirty-three Bracon mellitor females released per acre per week in a cotton plot at State College, Miss. from July 30 through August 27 maintained a consistently high population of this parasite until frost in mid-November. Beginning September 17, or 3 weeks after termination of Bracon releases, to mid-November, weekly dissections of shed fruit showed that an average of 48% of the weevil larvae were parasitized.

Personnel of the Boll Weevil Research Laboratory of State College, Miss. found that a little known braconid parasitized a high percentage of boll weevil larvae in Guatemala. In Alta Verapaz Urosigalphus schwarzi Cwfd. parasitized 38% and 60% of larvae infesting dooryard Gossypium hirsutum and G. barbadense, respectively.

2. Bollworms. The nuclear polyhedrosis virus was tested against bollworm-tobacco budworm complex in field experiments on cotton in 1964. In one experiment at Brownsville, Tex. a dosage equivalent to 1,000 diseased larvae per acre was more effective than 100 larvae per acre. A dosage of ten larvae per acre was no better than the check. In another experiment a dosage of 100 diseased larvae per acre was as effective as 2 pounds of toxaphene plus 1 pound of DDT per acre. The population consisted of a high percentage of tobacco budworms and Shell SD-9129 at 0.8 pound and Bayer 44646 at 2 pounds were more effective than the virus or toxaphene plus DDT. At Waco, Tex. a dosage of 100 diseased larvae per acre gave control of a light bollworm infestation equal to that obtained with carbaryl at 2 pounds per acre. In 2 experiments at Stoneville, Miss. a dosage of 100 diseased larvae per acre reduced bollworm injury below that of the check. At Tallulah, La. a dosage of 100 diseased larvae per acre gave bollworm control equal to that of 1 pound of DDT per acre. A dosage of 10 diseased larvae per acre was ineffective.

In laboratory tests at Brownsville, Tex. the Heliothis virus was compatible with the following insecticides, combination of insecticides, and insecticide adjuvants: endrin; DDT; toxaphene; carbaryl; toxaphene-DDT; xylene; paired emulsifiers, Triton X-152 and X-172; spreader-sticker, Triton B-1956; wetting agent, Triton X-100; and a buffering material, Buffer-X. Mortality of larvae fed virus-methyl parathion mixture was reduced from 61.3 for the virus alone to 42.1 percent. Mortality of larvae fed a virus-CO₂-water mixture was reduced from 39.6 for the virus alone to 25.7 percent.

Four species of Heliothis were susceptible to the Heliothis nuclear polyhedrosis virus produced at Brownsville, Tex. The Heliothis species infected with this source of virus were: H. zea (Boddie), H. virescens (F.), H. armigera (Hubner), and H. phloxiphaga (Gandr.).

Pink bollworm virus was transmitted to other Lepidoptera in the laboratory at Brownsville, Tex. Bollworm, tobacco budworm, and cabbage looper larvae became infected when fed on their standard rearing diets contaminated with the cytoplasmic polyhedrosis virus found in the pink bollworm laboratory culture. The virus could not be detected in the southern armyworm under similar diet contamination. It had not been found previously in laboratory cultures of the bollworm, tobacco budworm, and cabbage looper.

Parasitism of Heliothis eggs by Trichogramma in the fall was high on crops not treated with insecticides in the lower Rio Grande Valley of Texas. An average of 72% of Heliothis zea and H. virescens eggs collected during September-November on tomato plants, 52% on corn, and 17% each on pepper and on an experimental planting of cotton were parasitized. The corn and tomato fields were not treated with insecticides. The parasite showed no preference between the two hosts. H. virescens was not found on pepper and corn.

Parasites were reared on Heliothis larvae on artificial medium. A rearing method was developed and life-history studies made of Campoletis sp., the most abundant larval parasite of H. zea and H. virescens collected locally from wild and cultivated host plants near Brownsville, Tex. Young hosts were crowded on rearing medium in glass jars until after exposure to the female parasite. After a 1-day exposure they were removed and placed on fresh medium in individual containers. Hosts 3-5 days old were preferred for oviposition. Parasitism at this stage averaged 90%. Females parasitized from 9 to 49 host larvae with an average of 27 per female.

Parasitism of Heliothis spp. on cotton was greatest when insecticide usage was low. The proportion of eggs parasitized by Trichogramma was 4.3% in May, before the general use of insecticides, and 17.5% in late August following a decrease in insecticide applications after the middle of July. No egg parasitism was found in June and July when insecticide usage was widespread. Larva parasitism was 15.6%, 0.7%, 2.0%, and 3.3% for May, June, July, and August, respectively. The low parasitism during midseason undoubtedly was due to extensive insecticide applications at that time.

Two and one-half percent of 356 bollworm eggs collected from cotton fields near Tucson, Ariz. in 1964, were parasitized by Encarsia lutea (Masi).

The eulophid parasite Encarsia lutea (Masi) reproduces males parthenogenetically. A total of 105 bollworm and cabbage looper eggs from laboratory reared moths at Tucson, Ariz. were exposed to 203 virgin females that parasitized 40 eggs. Thirty-four male parasites were recovered from these parasitized eggs.

A high percentage of bollworm larvae collected from cotton in Mississippi in October, 1964 were parasitized. The percentage of Heliothis zea was 22.2 and of H. virescens, 20.

Preliminary results of studies conducted under contract by the Entomology Department, Mississippi Agricultural Experiment Station, indicate that a number of predacious insects are present in the cotton field during the growing season. These predators cannot withstand repeated, close interval applications of insecticides at late-season dosages and are reduced by repeated early-season applications. The studies also indicate that early-season insecticides can be applied in such manner so as to obtain economical

control of early season insects and preserve predators to aid in controlling later bollworm infestations. In general boll weevil infestations appeared to be the determining factor in starting regularly scheduled applications for cotton insect control.

3. Pink Bollworm. A virus, confirmed by symptomology and electron microscopy as a cytoplasmic polyhedrosis virus, has been isolated from larvae and adult pink bollworms from a laboratory culture. This is the first record of a virus disease of pink bollworms.

Mattesia grandis collected from boll weevils infected other insects at Brownsville, Tex. In laboratory tests, the pink bollworm, cabbage looper, bollworm, and tobacco budworm became infected with M. grandis when the artificial media on which the insects were reared were surface-contaminated with spores. Observations indicated that pink bollworm larvae produced the greatest yield of spores and, therefore, might be used advantageously for laboratory production of the pathogen.

A virus reduced yield in pink bollworm mass rearing program at Brownsville, Tex. A cytoplasmic polyhedrosis virus caused considerable larval mortality, loss of adults which failed to enter traps, and sometimes a reduced fecundity of those that entered traps. In tests on virulence of the virus, the surface of the larval diet was contaminated with polyhedral inclusion bodies (PIB) at rates of 73.6, 735.6, and 7356.3 PIB/mm². These respective dosages resulted in larval mortalities of 12.3, 29.3, and 65.9 percent. The virus also reduced the weight and increased the development period of survivors.

4. Other Insects. Four percent of 492 cabbage looper eggs collected from cotton fields near Tucson, Ariz. in 1964 were parasitized by Encarsia lutea (Masi).

D. Insect Sterility, Attractants, and Other New Approaches to Control.

1. Boll Weevil. A large scale field experiment in Baldwin County, Alabama, combining diapause control with spring insecticide treatments or release of sterile males reduced boll weevil populations to very low levels. Eight applications of methyl parathion at 0.5 pound per acre at weekly intervals in the fall of 1963 were effective in reducing the boll weevil population on 135 acres on 20 farms. Woods trash examinations and inspection of trap plants placed in and near the treated fields were negative in the spring of 1964. The first boll weevil found in a treated field was during the week of June 15. Seven applications of 0.5 pound of Guthion plus 1.0 pound of DDT per acre were made to 10 fields during the period of June 15 to July 20. On August 26, 5 weeks after termination of insecticide treatments, the average infestation was 1.4% punctured squares with a range from zero to 5.5%. Sterile males were released at weekly intervals in 9 fields in numbers considered adequate to prevent normal reproduction. In 3 of these fields insecticides were programmed with sterile

releases. Dissection and hatch records showed that 64% of the eggs laid in these 3 fields failed to hatch. In the remaining 6 fields only non-viable eggs were found up to August 6. It was not until August 24 that viable eggs, or larvae, finally were found in all 6 remaining fields. These records, and data from shed fruit, show that both sterile male releases and chemical control drastically reduced the number of weevils in these tests.

Boll weevil populations were reduced in cotton treated with apholate spray at 1, 2, and 4 pounds per acre in one half-acre cages at State College, Miss. The treatments significantly reduced egg hatch, numbers of larvae in infested squares and consequently the number of emerging adults. Differences in treated and untreated cotton were evident several days after treatment. Phytotoxicity in the form of a significant reduction in square production was observed in the apholate treated cotton.

In tests at State College, Miss. dipping of male boll weevils in a 1% mixture of tretamine and apholate resulted in low mortality but insufficient sterility, whereas dipping in a 2% solution resulted in excellent sterility but excessive mortality. Two triphenyl tin compounds proved ineffective as chemosterilants for the boll weevil. Dipping of females, males, and both sexes in hempa resulted in little or no sterility with females alone and a slightly higher degree of sterility when both sexes were dipped than when only males were dipped. Several phosphoramides screened as chemosterilants were ineffective.

In studies at State College, Miss., of 38 candidate chemosterilants fed to boll weevils for 48 hours in sugar water only ENT 50987 showed promise. At 0.5 percent an average of 95% of the eggs laid were infertile. At a 5% concentration eggs laid on the 7th and 14th day failed to hatch. Thirty-six percent of the weevils died by the 14th post-treatment day.

In laboratory tests at State College, Miss. weevils exposed to dry film residues of apholate, tepa, and ENT 50987 laid sterile eggs. Mortality was very high with ENT 50987 but considerably less with apholate and tepa. It required 4 hours of exposure to tepa residue to achieve complete sterility and 24 hours for apholate and ENT 50987.

ENT 50987 and 50664 showed promise as boll weevil chemosterilants in laboratory tests at State College, Miss. In preliminary dip tests with mixed sexes, 14 day post-dip mortalities with ENT 50987 ranged from 30 to 74%. All eggs laid 7 and 14 days after treatment failed to hatch. Some hatch occurred in eggs laid by weevils dip treated with ENT 50664.

In studies at State College, Miss. the response of boll weevils to a narrow band of light peaking at 510 nanometers increased with intensity up to approximately 40 microwatts/cm². The response appeared to level off at higher intensities. A 10-minute exposure period with 11-20 weevils per test appeared to give maximum response.

A rapid laboratory technique involving simple apparatus for bioassaying plant attractants for the boll weevil was developed at State College, Miss. In 51 replicated tests with this technique a water extract of cotton squares attracted more weevils than the checks. The ratios varied from 3:1 to 40:1 with an average of 8.5:1. The number of boll weevils responding ranged from 38% to 94%, with an average of 68.3%.

Plant attractant preference of the boll weevil to 11 species of Malvaceae was determined at State College, Miss. The order of preference follows: (1) C. digitata; (2) C. sulphurea (Texas); (3) G. hirsutum DPSL; (4) C. argentina; (5) T. populnea; (6) C. heterophylla; (7) C. involucrata; (8) C. sulphurea (Argentina); (9) A. esculentus (Okra); (10) H. clypeus and (11) H. syriacus.

Gas chromatography studies of the boll weevil plant attractant at State College, Miss. showed that at least 57 compounds are present in the square volatile fraction. These compounds include saturated and unsaturated aldehydes and ketones, saturated and unsaturated hydrocarbons (terpenes and sesquiterpenes), alcohols, acids and amines. Little evidence has been obtained for phenols and esters.

Stem treatment with American Cyanamid CL-47031 plus foliar spray of feeding stimulant showed promise against boll weevils in tests at College Station, Texas. In a large field cage test with American Cyanamid CL-47031 applied as a stem treatment at 0.7 pound per acre or granular side-dressing at 10 pounds per acre, early season boll weevil control was obtained. The side-dressing was more effective than the stem treatment, but the 10 pounds per acre dosage caused some phytotoxicity. A side-dressing at 2 pounds per acre showed little promise. In a late season test with large, fruiting cotton the CL-47031 stem treatment alone was not effective; however, when the stem treatment was combined with foliar feeding stimulant sprays, considerable boll weevil mortality was obtained.

In a replicated cage study at Florence, S. C. the following treatments were compared to test weevil attractancy: cotton plants; cocklebur plants; forms covered with green painted plastic; and forms covered with red painted plastic. Field cages 6 x 6 x 36 ft. covered the treatments. The test area was bounded by woods on 3 sides and the nearest cotton was 300 yards to the west. The cages were inspected from May through September. Numbers of weevils collected were as follows: cotton, 182; cocklebur, 8; green forms, 3; and red forms 3. It appears that weevils located the cotton through odor since the cocklebur treatment was similar in mass and color and the green forms reflected similar light.

In studies at State College, Miss. significant differences were found in boll weevil feeding on extracts from seven species of Malvaceae. Weevil feeding on plugs containing extract from Gossypium hirsutum, (DPSL), Thespesia populnea and Cienfuegosia sulphurea was significantly higher

than on those containing Hibiscus syriacus, Callirrhoe involucrata, Callirrhoe digitata and Hibiscus sp.

Research on the isolation of boll weevil feeding stimulants found in the flower buds and flowers of cotton plants is conducted under contract by Southern Research Institute, Birmingham, Alabama. Semi-Annual Report No. 2 describes investigations of feeding-stimulant activity extractable by water and other polar solvents, such as methanol, and studies on the isolation of active components extractable by chloroform and non-polar solvents, such as hexane and ether. Boll weevil feeding behavior in the "rolled-plug" assay was inconsistent. Feeding on crude water and chloroform extracts was normal in January but became erratic early in February and frequently dropped to low levels. Erratic feeding in the assay continued through March and early April. During the latter part of April and in May feeding activity on crude water extracts reached high levels.

2. Pink Bollworm. At Brownsville, Tex. metepa-sterilized males released in a large cage test simulating natural conditions reduced pink bollworm populations 80-90% below that of an untreated check. The estimated release ratio for the season was 7:1 (sterile male: existing natural moths) and varied from 1:1 to 186:1. However, populations increased despite the release of sterile males. The study is being continued to take advantage of mortality from cultural practices and other factors affecting overwintering populations.

Use of sex lure traps failed to reduce pink bollworm field infestation at Turreon, Mexico. Although over 12,000 males were collected over a $2\frac{1}{2}$ month period in 49 traps, first-generation infestation was the same as that in an adjacent part of the field without traps. Lack of isolation and other factors may have resulted in the ineffectiveness of the trapping. However, considerable information on use of the sex lure traps was obtained during the season.

The duration of activity of the pink bollworm sex lure was not influenced by different solvents in tests conducted in the fall of 1964 at Brownsville, Tex. Traps baited once with 100 female equivalents of the lure dissolved in acetone, benzene, hexane, methylene chloride, or ethyl ether captured as many males as traps baited twice weekly with similar amounts of methylene chloride extract for a period of 3 weeks. After this time their catches dropped below those of the trap baited twice a week. No differences between solvents were noted.

In studies at Brownsville, Tex. female pink bollworm moths sterilized with metepa were competitive with normal females. Dosage of technical metepa topically applied required to sterilize females was 60 µg/moth. At a dosage of 30 µg/female, 10% of the eggs deposited hatched. Treated females were competitive with normal females at dosages from 30 to 60 µg when caged with normal pairs so that the ratio of treated to normal females was 4:1.

E. Evaluation of Equipment for Insect Control and Detection.

1. Boll Weevil. In an isolated field test in Florida, a flail type machine for destroying fallen weevil-infested squares held the infestation over an 8-week period to a maximum of 10.2%. A nearby untreated check had an infestation of 46% punctured squares 10 days earlier when insecticide treatments were begun. The treated area received 5 treatments with the flail machine beginning before emergence of F₁ weevils.

2. Bollworms. High frequency sound affected moth activity in studies at Florence, S. C. Sound in the range of 21 to 50 kc disrupts normal flight patterns of a number of tympanate moths including Heliothis zea. In preliminary studies the high frequency capacitor transducer developed for bollworm studies was effective in reducing the attractiveness of one of a pair of black light traps to tympanate moths.

At Waco, Tex. fewer bollworm moths were collected in a black light trap in 1964 than in previous years. Only 7,215 moths were collected in a black light trap during 1964 which is the lowest number for any year of the 9 year period, 1956-1964. In 1963, 30,056 moths were collected.

In recent studies at Florence, S. C. with a high frequency microphone not previously available, it was determined that a switching artifact of 30-50 kc was present in the 200-4000 CPS stimuli used in 1963 H. zea acoustic studies. The moths were actually responding to the high frequency switching artifact rather than the low frequency stimulus. The switching artifact has now been eliminated through use of electronic switch to shape the pulse. The low frequency response limits have been redefined at 6-8 kc.

A high frequency transducer was calibrated with a B & K condenser microphone at Florence, S. C. The high frequency transducer used in the Heliothis zea studies was found to have a maximum output in the 60 KCPS range as determined with a recently acquired Bruel and Kjaer 0.25" condenser microphone.

3. Pink Bollworm. Pink bollworm sex-lure trap design and killing agents were investigated at Brownsville, Tex. Traps made of various cylinders about 10 inches in diameter with invaginated funnels or baffle plates appear superior to modified gypsy moth traps. A Steiner trap equipped with invaginated funnels also shows promise. Calcium cyanide was far superior to Vapona resin pellets as a killing agent placed in the traps in cage and field tests.

Pink bollworm moths collected in a light trap at Waco, Texas increased each year from 1953 to 1958 with the highest collections being made in 1958. Collections decreased sharply in 1959 with little difference in

numbers collected during the years 1959-1962. Fewer moths were collected in 1963 than in any year since 1954. In 1964 more moths were collected than in any year except 1958.

F. Varietal Evaluation for Insect Resistance.

1. Boll Weevil. Average emergence weights of boll weevils from field-collected squares of five cotton lines were nearly equal to weights of weevils reared from square powder diets from the same varieties. Emergence weights of weevils reared on Rex Smooth Leaf and Acala 4-42-77 were lower than for those reared on glandless Rex Smooth Leaf and glandless Acala 4-42-77 for both square-emerged and diet-emerged weevils. Pima S-2 produced the smallest weevils of any variety in the study. Lyophilized square powder diets with gossypol and gossypol gland contents added produced smaller boll weevils which took longer to emerge than a square powder diet containing no additional gossypol or gland contents. No weevils emerged on the diet containing 2% gossypol and only 1 weevil emerged on the diet containing 1% gossypol and only 1 weevil emerged on the diet containing 1% gossypol out of approximately 70 incubated vials. Pure gossypol was more toxic than gland contents.

In replicated oviposition tests with laboratory-reared weevils at State College, Miss., 15 cotton lines reduced boll weevil oviposition more than 15%. One line reduced oviposition 38%. Preliminary data indicate genetic control of this factor in the cottons under study. Twenty-four cotton lines produced boll weevils 18% smaller than those produced on DPSL. A standard antibiosis technique was used in these tests. Weevils required 2-3 days longer to develop from egg to adult on a few lines.

Tests at State College, Miss. indicated that glandless cotton is not more susceptible to boll weevils than glanded lines. Boll weevil feeding, oviposition and antibiosis experiments with 13 glandless "isogenic" cotton lines and their glanded parents show that the glandless genes $gl_2gl_2gl_3gl_3$, will not create a significantly greater degree of susceptibility to the boll weevil over glanded varieties. However care must be exercised in the initial selection of the genetic background in which the genes are placed.

2. Bollworms. Glabrous-nectariless cotton (1514) showed resistance to bollworm in field tests. Fewer bollworm eggs were laid on the cotton variety 1514 than on commercial varieties in each of four test fields at Brownsville, Tex., with seasonal average reductions ranging from 43 to 58%. Although all the fields were treated with insecticides for bollworm control, there were differences in square and boll damage between 1514 and check varieties. The seasonal average percent of damaged bolls, in respective fields of 1514 and the check were: 0.6 and 2.3; 2.5 and 4.2; 0.8 and 1.2; 3 and 5. Heavy fleahopper infestations developed in only one field, with fewer fleahoppers on 1514 than on the check in each of four weekly counts

totalling 138 compared with 738. Yields of 1514 compared favorably with check yields. At Waco, Tex., the bollworm infestation was light and there was no difference in bollworm damage among 1514, Lankart and Delta Pine Smooth Leaf. At Stoneville, Miss., 1514 had fewer squares and bolls damaged by bollworms than Delta Pine Smooth Leaf.

At Tucson bollworm larvae reared on glandless cotton foliage were heavier and developed faster than those reared on glanded cotton foliage. The average weight of thirty 10-day old larvae reared on a food medium made of Glandless (AXTE-25) cotton leaves supplemented with ascorbic acid and Brewers' yeast was 337 milligrams of 2.6 times greater than similar larvae reared on leaves from glanded cotton. The average development time from egg hatch to moth was 30.1 days for glandless leaf fed larvae and 34.8 days for glanded leaf fed larvae.

Heliothis larvae developed better on glandless than on glanded cotton in laboratory tests. Bollworm and tobacco budworm larvae were reared on lyophilized squares which had been reconstituted with water, agar, and mold inhibitors. Those reared on glandless square material were significantly larger than those on the corresponding glanded strains. In some instances the growth rate on the glandless strains was more than two times greater than on the glanded strains. Larvae of both species also grew larger on glandless cotyledons than on glanded ones.

In studies at Brownsville, Tex. experimental cottons inhibited growth of tobacco budworms. Lyophilized squares of lines from eight families were bioassayed for degree of inhibition of larval growth of the tobacco budworm. Results were similar to those previously reported for the bollworm. Larval growth was related to gossypol content of the seed and squares. Generally lines with the higher gossypol content produced smaller larvae. However, a few lines with relatively low gossypol content produced larvae that were smaller than those from a DPL-15 standard. Of 87 lines tested, 38 produced larvae smaller than those from the standard. The larvae on all lines were larger than those from Pima S-2 which had a higher gossypol content than the experimental lines.

Bollworm survival, growth rate, and pupation was affected by gossypol in studies at Tucson, Ariz. In laboratory tests when 0.3% gossypol was added to lima bean food medium, larval mortality was 50% greater than in the checks. The average weight of 10-day old larvae on the diet containing gossypol was only 3.6 mg compared with 590 mg for those on the checkouts. Gossypol levels as low as 0.075% noticeably reduced larval weights. Ninety two and five-tenth percent of the larvae pupated with 15 days on the check diets while 75% pupated in 15.8 days on the diet containing 0.05% gossypol level and 45% pupated in 41.6 days at the 0.3% level.

In studies at Brownsville, Tex. growth rate of Heliothis larvae was related to gossypol content of cotton plant. It has been previously reported growth rates of H. zea and H. virescens larvae were greater on diets of glandless than on glanded lyophilized cotton squares and cotyledons of six isogenic strains.

Chemical analysis showed that squares and cotyledons of the glanded strains had several times the gossypol content of the glandless strains. Larval growth appeared to be directly related to the gossypol content. Previous work has also shown that glandless plants were highly attractive to several insects that rarely attack commercial varieties.

In studies at State College, Miss. reciprocal grafts of Rex S. L. glanded and glandless cotton showed a reduction in free gossypol in squares from glanded scions compared with squares from glanded stocks and non-grafted glanded plants. The data supports the hypothesis that gossypol or a precursor is produced predominantly in the roots of glanded plants, that glandless plants have a reduced ability to produce and to store gossypol, and that gossypol is translocated in some form.

Cienfuegosia exhibits genetic characters needed in cotton for resistance to insects. The genus Cienfuegosia is known to have numerous glands in vegetative parts but the seeds are gland-free. Chemical analyses at Brownsville, Tex. showed that the gossypol content of vegetative parts was high but that of the seeds was extremely low. If this condition existed in cotton the glandless seeds would provide gossypol free meal which would be a source of protein for human and non-ruminant animal consumption.

3. Other Insects. Grape colaspis (Maecolaspis flavida) and striped blister beetle (Epicauta vittata) readily attacked glandless lines of cotton. Approximately 28 different "isogenic" glandless lines were damaged by grape colaspis while their glanded parents and other glanded lines were not damaged. Striped blister beetles moved into large field plots of Rex Smooth Leaf and Acala 4-42-77 glanded and glandless lines and Delta Pine Smooth Leaf, damaging only the glandless lines.

Laboratory feeding tests at Tucson, Ariz. indicated that high gossypol cotton varieties are more resistant to beet armyworm larvae than low gossypol varieties. The average weight of 10-day old larvae reared on leaves of low gossypol strains (.042% or less gossypol), AXTE Glandless, A-44-10-1 and Dwarf AXTE-Lankart F₂ were 8.6, 4.64, and 4.17 grams, respectively. This compared with an average weight of 1.38, 1.32, and 1.27 grams for larvae reared on leaves of high gossypol strains (0.1 + gossypol), Red dwarf, Pima 32, and 63-11 #1, respectively.

In laboratory studies at Tucson, Ariz. salt-marsh caterpillar larval development was inhibited with 0.1 percent gossypol added to diet. Average weights of 10-day old salt-marsh caterpillar larvae fed lima bean food media with 0.1 gossypol acetate added was only 1.1 milligrams compared with 82.4 milligrams for those reared on the same diet without gossypol. Mortality when larvae were 10 and 14 days old was 33 and 60 percent, respectively, compared with none in the check.

A low concentration of gossypol was lethal to salt-marsh caterpillar larvae. In laboratory feeding tests at Tucson, Ariz. 0.1% or more gossypol added to lima bean food medium resulted in 100 percent mortality within 20 days. At 0.025% gossypol the average weight of surviving 10-day old larvae was only 28.5 mgs compared with 67.5 for the check diets. The number of required days to pupation was more than doubled at the 0.05% gossypol level and 10 days longer than for those in the check at the 0.025% level.

In studies at Tucson, Ariz. glandless strains of Acala cotton were much more susceptible to white flies than their glanded counterparts. Leaf collections on June 9 showed 7 and 25 times more eggs and 4 and 3 times more adults on glandless AXTE and Acala 4-44-77 strains respectively, than on their glanded counterparts. Differences also were similar in collections made on June 16.

In studies at Brownsville, Tex. experimental cottons were resistant to cotton fleahopper and cotton aphid. Of 16 strains used in a field experiment, 4 showed resistance to cotton fleahopper. Glabrousness appeared to contribute to this resistance. Strain 1514, which is glabrous and nectariless, was outstanding in this and in another field experiment and in a cage experiment. It does not appear likely that absence of nectaries is associated with resistance to fleahopper. No obvious differences were noted between glanded and glandless strains. In the cage experiment, cotton aphid populations were lower on seven glabrous strains than on M-8 which is hirsute.

G. Insecticide Residue Determinations.

In cooperation with the Plant Pest Control Division a large number of soil samples were analyzed at Tifton, Ga. and Kerrville, Tex. for methyl parathion or for arsenic for the Mississippi River Basin pesticide monitoring program. A large proportion of the samples analyzed for methyl parathion showed the presence of this insecticide but in amounts less than 1 ppm. The arsenic residues ranged generally from about 0.5 to 19.0 ppm with the greater number of samples falling near the 10 ppm level.

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TILLAGE, PLANTING, FERTILIZING, HARVESTING,
HANDLING OPERATIONS AND EQUIPMENT, AND PEST CONTROL

Agricultural Engineering Division, ARS

Problem: The greatest need in cotton production is cost reduction. Research on tillage, planting, fertilizing, harvesting, handling operations and equipment, and pest control will help reduce these costs. Tillage of the soil is the greatest consumer of power in the production of crops. Some type of tillage operation is considered necessary for most crops but there is evidence that much unneeded and in some cases detrimental tillage operations are performed. Intensive research is needed to determine the optimum tillage requirements based upon costs and crop response, for various soil, climatic and crop conditions. More basic knowledge of the micro-environmental requirements of the cotton seed is needed; and this needs to be translated into planting equipment to give better precision in the control of seedbed physical conditions. Better control of the seedbed shape, size, spacing and seed position will also have a direct bearing on the economy of using new and more potent pesticides.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

The cost of harvesting and farm handling is a major expense of production. With the supply and adequacy of manpower for these operations becoming less satisfactory, the need for improvement on harvesting equipment and methods becomes more acute.

To minimize the use of possible hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of cotton production and harvesting in cooperation with experiment stations and the farm equipment industry. Tillage, planting and fertilizing

practices on cotton have been under investigation in several states. Pest control equipment research on cotton is conducted at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; and Lubbock, Texas; and (particularly boll weevil control) at State College, Mississippi. Electrical and physical methods for cotton insect control are studied in South Carolina and Texas, with the Texas project contributing to the Regional Research Project S-37, "Basic Factors Involved in Control of the Pink Bollworm."

The Federal scientific effort devoted to the effect of tillage practices on plant growth is 1.2 professional man-years. There were 2.8 pmy's devoted to cotton seedbed preparation, planting, and fertilizing equipment; 3.1 to pest control in cotton; 4.4 to cotton harvesting and handling operations. A total of 5.9 pmy's are devoted to electric traps in insect survey detection and control.

PROGRAM OF STATE EXPERIMENT STATIONS

Problems concerned with seedbed preparation, planting, fertilizing, harvesting, handling operations and equipment, and pest control are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Effect of Tillage Practices on Plant Growth

In the soil-mixing study at Stoneville, Mississippi, large field plots of Tunica silty clay soil, a stratified clay over sand deposit, were deep-plowed or mixed with a ditcher in 1962. After one crop year the plots were in good physical condition for tests. Good stands and high yields of cotton on the deep-treated plots were significantly better than shallow tilled checks this year. The longevity of this treatment is being recorded.

Effect of the crop preceding, and the depth of seedbed preparation on production, cooperative with Georgia, was continued. The area was prepared and planted to corn, cotton, soybeans, and winter rye grass. The results of these investigations from the last two years continued to indicate that the previous crop had greater influence on the yield than the tillage used.

Precision tillage (where the subsoil slot is placed precisely under the intended row of cotton) was found to be as effective applied in field capacity moisture soil as in drier soil as measured by plant response and yield at Shafter. Vibrating subsoil shanks used as precision tillage equipment were shown to be no more effective than rigid shanks in increasing cotton yield in certain soils. Cotton plant height and yield were shown to decrease as the soil compaction was increased. The yields were the same for all plots when precision tillage was used. Precision tillage 20 inches

deep under the seed row was evaluated on irrigated and dryland Amarillo loam soil at Lubbock for the third year. No yield increase over conventional seedbed preparation was observed in the 1964 study. At Stoneville for the third consecutive year, well-pulverized seedbeds resulting from secondary tillage with a disk harrow improved emergence and survival of cotton plants, but did not improve yields.

B. Cotton Seedbed Preparation, Planting and Fertilizing Equipment

In crop residue disposal studies at Stoneville, design changes incorporated in a new shredder-tiller residue disposal machine permitted faster field speeds and maintained disposal efficiency by changing rotor rotation and modifying tiller shields. An experimental complete-disposal device assembled in 1963 was field tested and dismantled for extensive design.

In seedbed preparation tests at Shafter, a minimized tillage system was compared to a normal system. Third-year results show no difference in yield with a system that requires only 30 percent of the horsepower hours of the normal system. A profile of the soil strength shows that three different conditions have been created in the minimized system: (a) high surface strength for tractor traffic, (b) low surface strength in the irrigation furrow and (c) low strength to 26 in. deep in the rooting zone.

Field tests of planting equipment on a Bosket very fine sandy loam at Stoneville indicate a definite relationship of soil conditions and soil treatment at the time of planting to cotton plant emergence. Soil conditions altered by some planting equipment resulted in slower emergence, poorer stands, and delayed maturity, but did not affect total harvested yields. In comparative tests at Lubbock, the precision-depth planter developed last year was superior in earliness and uniformity of plant emergence. Press wheels on the covering soil provided a slight increase in maximum seed zone temperature and reduced moisture loss; however, the higher soil strength produced by pressing the covering soil decreased cotton seedling emergence. Vibrating covering soil attachments did not increase seedling emergence or yield of cotton.

Plant population and spacing-plots at Lubbock were planted flat in rows spaced 5, 10, 20, 30 and 40 in. apart and on 40-in. spaced beds using two rows per bed spaced 4, 8, 12, and 16 in. apart. Populations ranged from 20,000 to 500,000 per acre. Marked differences in earliness and difference in yield were observed due to the row spacing and population treatments. Varying plant population and hill spacing on a Bosket very fine sandy loam at Stoneville resulted in pronounced differences in plant characteristics and seed cotton yield in a very dry growing season. Hills spaced 36 in. apart and containing from two to five plants per hill produced three of the five top yields in a total of 16 treatments. Hills 12 in. apart with one and two plants per hill accounted for the other two top yields.

C. Pest Control Equipment for Cotton

Nozzle wear studies were revised at Auburn to determine the effects of orifice size and pressure on wear, and the effects of cross winds on spray patterns. After spraying diuron (DW) for 30 hours at 40 psi, the increase in discharge was 13.3 percent for a brass nozzle applying 0.336 gpm as compared to 9.1 percent for a nozzle applying 1.012 gpm. (Wear was a more serious problem with the smaller nozzle.) The increase in discharge after spraying diuron (DW) for 30 hours at 40 psi was 13.3 percent as compared to 6.9 percent after spraying at 20 psi. Cross winds of 10 mph caused distortion and shifting of spray pattern. Greater distortion occurred when operating at 20 psi than 40 psi.

The development of automatic controls for chemical placement in connection with planting and for other preharvest operations was begun at Stoneville, Mississippi. A two-row experimental machine was designed and evaluated for automatically hilldropping cottonseed and applying precisely-sized spots of agricultural chemicals at specified locations in and around the hill of cotton. Pneumatic, electrical and mechanical energy were used to operate the various components of the machine. An automatic chopper for weed control between hills of cotton was also developed as a research tool. Controls of this type permit the precision placement of seed, mechanical operations, and several chemicals in specific locations with respect to each other. The first year's experiments gave promising results.

Weed control in skip-row cotton poses a greater lay-by problem than solid cotton. A high and wide (HAW) machine was designed for cultivation and chemical applications in the skip-row cotton in Mississippi. It performed satisfactorily in cotton up to six feet tall, maintaining a weed control program until harvest time. It was equally effective in younger cotton. Deficiencies encountered were difficult turning and inadequate horsepower from the 26 h.p. engine for spraying and cultivating the 120-inch swath. A mixture of EPTC and diuron applied subsurface with this machine gave better lay-by weed control than conventional lay-by treatments. Shallow tillage after this chemical application extended the effectiveness of late-season control.

Chemical weed control equipment studies included basic and applied research on soil incorporation and subsurface application of chemicals. Techniques for rapidly and accurately measuring the distribution of pesticides placed in the soil were improved upon in Mississippi and California. The techniques are the same but the equipment used is slightly different. Basic work on power-driven incorporators in California continued to provide data on operating characteristics. Data indicates that mixing efficiency increases with rotor diameter and with relative velocity of the rotor to forward speed. Power requirements increased with relative velocity and with smaller soil "bites". Energy requirements for 8, 12, and 16-inch rotors were the same when other factors remained constant.

Soil incorporation studies were conducted in Alabama to determine the effects of incorporation on three different pre-emergence chemicals and to evaluate incorporating tools and depth of incorporation. Trifluralin was incorporated with five different tools. Weed counts showed no difference in weed control with different tools. Incorporating trifluralin from one inch to five inches deep did not affect weed control nor the yields of cotton. Soil incorporated trifluralin had only six percent as many weeds as surface applied trifluralin. Soil incorporated CIPC had 45 percent as many weeds as the surface applied CIPC. Diuron, incorporated, when compared with diuron, surface-applied, showed no difference in weed control.

At Lubbock, Texas, band incorporation with a row wheel and blade improved the weed control action of five pre-emergence herbicides -- diuron, Treflan, Prometyrne, Dacthal 75W and Herban. Incorporation of broadcast application of herbicides gave full-season control in narrow-row cotton. Pre-emergence chemicals gave more satisfactory weed control when applied to 40-in. row cotton planted on beds than when applied to cotton planted in the lister furrow.

Preliminary work was begun in Mississippi to develop equipment for precision placement of post-emergence subsurface herbicides in heavy clay soils. In exploratory tests, solid-stream nozzles positioned above ground level behind eight-inch disk coulters were compared with knife injectors using EPTC. The coulters arrangement proved to be unsatisfactory. However, control with knife injectors on each side of the crop and a directed spray of DMA and a surfactant in the drill area gave excellent weed control. The knife injectors were attached to the same applicator as the DMA nozzles. One year's results justify intensive efforts next season.

Further investigations were made on the triband concept of weed control with special emphasis on the Stoneville, Mississippi, blade applicator and a newly-designed knife-injector applicator. Minor modifications also were made on the planting units to improve performance. Evaluation trials again were conducted on sandy loam and silty clay loam soils. Satisfactory results were obtained on the sandy loam with the Stoneville blade, whereas the knife-injector applicator performed best on the silty clay loam.

Several nematocide placement tests in California indicated the effectiveness is greatly increased when combined with precision tillage (where the subsoil slot is placed precisely under the intended row of cotton) either in the same operation or a following operation. Consistently higher yields were obtained when the nematocide was released at the bottom of the subsoil shank or 20 to 24 inches deep.

In the area of boll weevil control, studies on mechanical methods of destroying fallen cotton squares were continued in cooperation with ENT at State College, Mississippi. An improved model of the flail machine was built and tested to determine its efficiency in square destruction and its effectiveness in boll weevil control.

Tests were made in two isolated spots in Florida. When five machine treatments were made in 22 days, the infestation reached a maximum of 10.2 percent in an eight week period compared to 46 percent ten days earlier in the check. Pickup efficiency was 84.5 percent. At the other location, infestation did not reach damaging numbers, but it was lower in the treated plots. At State College, migration masked the overall effects of the early treatments.

In tests to improve the drill area pickup efficiency, cup-type brushes in conjunction with an air blast gave 85 percent efficiency in the drill. The killing efficiency of the machine was 96.3 percent on the immature weevils which passed through the flail units.

D. Cotton Harvesting Equipment

The topping and vertical trimming test was continued at Stoneville for the third year. Topping rank-growing Stoneville 7A cotton plants on three different dates (July 20, August 5, and August 20) and trimming lateral branches just as they began to lap in the row middle (July 24) had no effect on seed cotton yield lint grade, staple length, or picking efficiency. There was slightly less foreign matter in the machine-harvested seed cotton and lint from the topped and laterally-trimmed plots than from the untreated plants although no differences were obtained among the topped and trimmed treatments. Boll rot loss was reduced slightly by early topping (July 20) in an area where the average boll rot loss was less than 5 percent. Although plant lodging was not a problem in this area in 1964, it was observed that plants in the topped plots were more erect.

Sources of trash contamination during the mechanical harvesting operation were identified by the process of eliminating the major contributing factors before harvesting. Based on 3-year's data from this test at Auburn, the following conclusions have been reached: Ground trash is not a source of contamination. The picker, whether "clean" or "dirty," is not a source of contamination. Boll bracts constitute a large portion of the fine trash, indicating that a bractless cotton would be desirable for mechanical harvesting. Leaf trash constitutes about 20 percent of the total trash, even in well-defoliated cotton. Burs constituted an average of 50 percent of the total trash but varied greatly from year to year, depending upon deterioration of burs before harvesting.

A study of plant characteristics for mechanical picking at Stoneville included six widely different cotton varieties. More trash was harvested with Stoneville 7A, and the Delta Smooth Leaf variety had less trash in the ginned lint; however, there was no significant difference in lint grade and staple length. Delfos 9169 had the highest yield and picker efficiency, but there was no significant difference in the yield of Delfos 9169, Stoneville 7A, D & PL Smoothleaf, and Lankart 57. Yields and picking efficiencies were higher than usual and preharvest losses were very low as a result of excellent growing and harvesting conditions in 1964.

A technique utilizing a pendulum was developed at Auburn for measuring picking energy required to remove cotton from bolls. Strain gage equipment was used for similar measurements at Stoneville. These tests are designed to give cotton breeders a better criteria for evaluating the picking characteristics of cotton. For seven varieties having a moderate to low range in storm resistance, total field loss (including preharvest weather loss) decreased as picking energy increased at Auburn. This apparently does not hold true over wider extremes of storm resistance because of storm losses. Similar tests at Stoneville with the six varieties with widely diverse storm-resistant characteristics showed a relationship between the average peak force involved in removing a lock of cotton from the boll, the carpel angle of the boll, and picker efficiency. Lankart 57, a storm-resistant variety, required the most force for removal with an average of 162 grams, while Stoneville 7A, a typical open-boll variety, required an average of only 70.7 grams.

There was no interaction of picker drum height and plant population on picker efficiency. As drum height varied from 1 to 4 inches, the picker efficiency remained constant and was the same for plant populations of 10,000, 20,000, 40,000, 60,000 80,000, and 100,000 plants per acre. There was a definite decrease in harvested yield at populations greater than 60,000 plants per acre.

Picker efficiency was not affected by different skip-row patterns. The increase in harvested yield over the solid planted cotton at Auburn was 25 percent for the plant-two-and-skip-two pattern and 21 percent for the two-and-one pattern.

A 3-year study comparing the fiber qualities and spinning performance of cotton harvested with three types of spindle cotton pickers and by hand was completed at Stoneville. Results showed (1) no differences in lint grade between types of picker; (2) one-half grade increase in lint grade for hand harvesting compared with mechanical harvesting; (3) more short fibers in handpicked than machine-picked cotton, probably because of somewhat selective picking by the mechanical pickers; (4) no differences in

fiber strength between handpicked and machine-picked cotton; (5) lower foreign matter in lint from handpicked cotton, which was reflected in lower picker and card waste in manufacturing; (6) little difference in spinning performance between handpicked and machine-picked cotton except in yarn strength and ends down; and (7) lower ends down at the 90 percent statistical level for one type spindle. This work has been completed and published.

Equipment for laboratory studies of picker performance was improved at Auburn and Stoneville. A mechanism for pulling the stalk-carrying trolley through the picking unit at synchronized speeds with the picker head, was designed and installed at Stoneville. A second glass pressure plate was built for the rear drum of the laboratory picker to facilitate the use of highspeed movie cameras on both drums of the picker. A series of highspeed movies was then taken of the picking action as stalks of open cotton passed through the picking unit. Improvements in highspeed photography techniques were suggested in preliminary trials. The movies gave additional emphasis to possibilities of removing trash within the picker head before it becomes entangled with the seed cotton.

The following information was obtained with the laboratory model cotton picker at Auburn: Boll exposure or picking time ranging from .16 seconds to .28 seconds did not affect spindle efficiency. The spindle efficiency for fluffy bolls was 95 percent compared with 90 percent for weathered bolls and 65 percent for knotty bolls.

The effect of spindle speed on spindle efficiency varied with boll type. For fluffy bolls, efficiency increased as the speed increased from 700 to 2,300 r.p.m., remained constant between 2,300 to 3,900 r.p.m., and decreased slightly at 4,700 r.p.m. Picking efficiency of knotty bolls increased linearly as spindle speed increased from 700 to 3,900 r.p.m. Picking efficiency of fluffy bolls was not affected as spindle spacing varied from 1-5/16 to 1-13/16 inches but decreased significantly as spacing was increased another 1/4 to 2-1/16 inches. For knotty bolls, the efficiency decreased significantly for each one-fourth inch increase in spacing. The position at which the bolls entered the spindles also affected efficiency. Greatest efficiency was obtained when the boll was centered among four spindles. Poorest efficiency occurred when the spindle was centered on a boll. Spindles from the bottom three rows of a picker which had picked 150 bales had a picking efficiency about 5 percent lower than that of new spindles. The respective barb wear was 20, 15, 10, 5, and 3 percent for the first, second, third, fourth, and fifth barbs from the spindle tip. The remaining nine barbs showed no evidence of wear.

In a comparison of types of mechanical harvesters at Auburn, the flexible roll stripper had an efficiency of 98.6 percent as compared to 90.6 percent for the spindle picker. Due to the lower grade of the stripped cotton, the gross value of the harvested lint from four bales harvested in an alternate two-row comparison was the same for both machines.

Research on stripper-type harvesters at Lubbock indicated that burr extractors on the harvester may be feasible when used in combination with the USDA green boll separator. The broadcast cotton harvester designed by the project was improved by minor modifications, and its performance in narrow-row stormproof cotton was satisfactory.

In field storage and handling work at Lubbock, burr cotton was run through extractor-feeders, baled in the gin press, and then stored outside on pavement. One bale was removed and ginned in March, July, September, and December. Fiber deterioration had begun after 1-year's exposure and 12.92 inches of rainfall. Strength, length, and grade had decreased and the cavitoma reading increased in the December 31 ginning.

A preliminary investigation of field transport equipment was begun at Lubbock, looking toward more efficient handling in the field and unloading at the gin. A bottom dumping basket was used to determine the maximum density burr cotton that would fall from a basket or trailer under its own weight. The maximum density established in these tests was in the range of 9.0 to 10.5 lbs. per cubic foot.

E. Electric Traps for Cotton Insects

Laboratory and field studies relating to the use of visible and near-ultraviolet radiant energy for attracting and collecting various species of cotton insects were continued in 1964 at College Station, Texas. Studies were cooperative with the Texas Agricultural Experiment Station and the ARS Entomology Research Division Laboratories at College Station and Brownsville, Texas. The Physics Department, Texas A&M University, cooperated informally in certain phases of these studies. This project contributes to Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm".

In cooperation with entomologists of the Cotton Insects Systemic Chemicals Investigations, ENT, College Station, Texas, group response techniques and Y-shaped test chambers were used in spectral response studies with adults of the boll weevil (Anthonomus grandis Boheman), the bollworm (Heliothis zea (Boddie)), and the tobacco budworm (Heliothis virescens (Fabricius)). Work with the boll weevil using a single stimulus technique, ten different wavelengths in the 315- to 615-millimicron (mp) region, and three stimuli energy levels confirmed previous test results showing a response peak in the blue-green region at approximately 500 mp. No shift in response peak was apparent within the range of intensity levels tested.

Work on attractance of bollworm and tobacco budworm moths to radiant energy has revealed the need for testing techniques which will better evaluate

differences in moth response to specific wavelengths. Emphasis in laboratory work has been shifted to studies with the bollworm and tobacco budworm. No further laboratory work with the boll weevil is planned at the present time. Information resulting from these action spectral studies will provide a basis for specifying emission requirements of an efficient attractant lamp for the bollworm and tobacco budworm.

Work has continued in cooperation with biophysicists of the Physics Department, Texas A&M University, in developing techniques and equipment for electroretinogram (ERG) studies with insects. An ERG study has been made of the spectral sensitivity of the compound eye of the boll weevil. The spectral sensitivity curve indicates there are two distinct regions of peak sensitivity. One peak is at 518 mμ and the second at a point yet to be determined in the ultraviolet. In carrying out this study, an effort was made to develop equipment and techniques which are adaptable to most insects. The next phase of this work will be ERG studies with the bollworm and tobacco budworm. Similarity of results obtained with the boll weevil by group response and ERG techniques indicates some promise for utilizing ERG response determinations as a means of predicting phototactic responses of insects to radiant energy stimuli.

Limited studies on the response to light of the boll weevil were continued in cooperation with the Entomology Research Division, ARS at the Boll Weevil Research Laboratory, State College, Mississippi. For purposes of establishing standard testing procedures, tests were conducted on the effects of numbers of weevils per test, dark preparation period, exposure time, and intensity on the response of the insects. Results indicate that weevil response decreases as the number of weevils per test increases. Intensity appears to influence weevil response favorably as it is increased.

More tests are necessary for conclusive results, and work will be continued to establish these factors.

F. Cottonseed Studies

In tests at Knoxville, Tennessee on cottonseed containing a high percentage of hard seed, audiofrequency glow-discharge treatments increased germination at 2 days from 24 percent for the control to 83 percent for the best exposure. A field test using Empire WR machine-delinted cottonseed at Knoxville did not reveal any improvement in germination or yield of cottonseed due to electrical treatment. Significant increases in yield however were observed in cooperative experiments with Texas A&M University for one treatment of Empire WR and Lankart SEL cottonseed. RF treatment also accelerated emergence and increased the yield for the Empire WR variety.

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COTTON GINNING

Agricultural Engineering Research Division, ARS

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed and trash, packaging, and sampling in order to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Rapid methods of harvest which have come into widespread use during the past 20 years have been successful because of the advances made in cotton ginning research.

Although developments growing out of the USDA Ginning Research Program have been revolutionary, there are many problems yet to be solved, some of which are growing acute. There is increasing need for further automation of the ginning processes to effect better quality control and reduced labor costs.

In their quest for lower unit costs, mills are continually demanding more and more of cotton as they increase machine and processing speeds. At the same time the trend continues in the trade to demand cleaner and cleaner cotton. Thus with the farmer gathering more and more foreign matter with the cotton, the cotton trade demanding cleaner fiber for a given grade, and the manufacturer demanding more and more performance, the gin's role becomes most complex. More efficient cleaning equipment which will minimize fiber degradation at reduced labor and power costs is among the more urgent needs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, materials handling engineers, and systems engineers engaged in both basic and applied research on the engineering phases of cotton ginning and handling. Seed cotton handling and storage and seed cotton conditioning and conveying research is currently being conducted at Stoneville, Mississippi, and Mesilla Park, New Mexico. Research on seed cotton conditioning, seed cotton cleaning, gin stands, gin performance and cotton quality, and waste collection and disposal is being conducted at Clemson, South Carolina; Mesilla Park, New Mexico; and Stoneville, Mississippi. Lint cleaning studies, packaging, and cottonseed research is conducted at Stoneville. Research is cooperative with state experiment stations, Economic Research Service, industry, and individuals, as well as with other Divisions in the Agricultural Research Service.

The Federal engineering effort devoted to research in this area totals 16.5 professional man-years. Of this number, 0.6 is devoted to seed cotton handling and storage, 1.3 to seed cotton conditioning, 2.4 to seed cotton

cleaning, 0.8 to conveying, 2.0 to gin stands, 5.5 to gin performance and cotton quality, 0.5 to lint cleaning, 0.5 to packaging, 0.5 to cottonseed, 1.9 to waste collection and disposal, and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is conducted in only two State agricultural experiment stations; namely, Oklahoma and South Carolina. The Department has been specifically concerned in this area for several years and has carried on the major program of research on the engineering phases of premarket cotton processing and handling.

The Oklahoma research involves the adaptation and testing of cotton ginning equipment, techniques and related operations for reducing the cost and delay in handling and conveying seed cotton on the gin yard and in the gin. In addition, evaluations are being made of the quality reductions associated with green and immature bolls in harvested cotton as well as determination of the effects that various combinations of cleaning, drying, and ginning machines have on returns to the producer.

The South Carolina studies are concerned with the development of new principles and techniques for ginning cottons. Characteristics and properties of seed cotton, lint, and seed related to the basic ginning processes are being investigated as well as the effects that various physical actions have on fiber and seed.

A total of 3.3 man-years are devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seed Cotton Handling and Storage

1. Following preliminary investigations last year an unloading system was designed and constructed at Stoneville. The system consists of a specially designed dump trailer, receiving hopper and automatic seed cotton metering device for feeding cotton at a uniform rate directly into the first stage drying system. If successful in tests, a sizable reduction in labor and power would be effective.

Research work was initiated at Mesilla Park during Fiscal Year 1964 on the development of another system for a more efficient and economical seed cotton unloading system. A pilot model system, which is completely different from conventional systems, was designed, constructed, and tested. This system consisted of an inclined unloading ramp, receiving hopper, feeding mechanism, and air-jet conveyor. A side-dumping cotton trailer with inclined bottom was positioned on an inclined unload-ramp which permitted the seed cotton to be dumped from the trailer into the receiving hopper. The feeding mechanism in the hopper bottom fed the cotton at a uniform rate onto the air-jet conveyor. In preliminary tests this system appeared to be practical and workable. Data obtained from performance tests indicated that

a system of this type would require only about one-fifth the horsepower used by conventional unloading systems which would be a reduction from approximately 100 horsepower to 20 horsepower.

B. Seed Cotton Conditioning

1. At Stoneville, using a zero-gradient moving bed drier, 288 test lots were dried and ginned to study the effects of (a) initial moisture content, (b) air-cotton mass ratio, (c) drying air temperature, and (d) exposure period on quantity of moisture evaporated. In each instance, the drying factor relationships were reduced to quantity of moisture removed per pound of fiber per 1,000 B.t.u. available from the drying air and showed that (1) most efficient use of heat resulted from reducing the air-cotton mass ratio, (2) for short exposure periods (5 seconds) the heat use efficiency is directly related to initial fiber moisture content but this relationship becomes obscured at 10-second and longer exposures, (3) the exposure period-moisture evaporated relationship is logarithmic, and (4) under conditions of the test temperature data differences were small and inconclusive except for gross moisture evaporated.

Also at Stoneville a 3-year study to determine the probable effect of agricultural chemical residues on the operation of an automatic drying system based on moisture determination via electrical resistance measurements was completed. Results for the first 2 years have been previously reported. Work on this project in 1964-65 was confined to the study of a soil-fed systemic insecticide. The growth phase, carried out in cooperation with Crops Research Division, is complete and certain findings, such as the delay in development of fruiting structures due to the systemic insecticide application and total final yields, are to be reported in an agronomy periodical. The electrical resistance measurement phase is in progress but has required development of a special measuring circuit.

At Mesilla Park, basic studies are being made on the effect of changes in temperature on electrical resistance of cotton.

Checks were made of a commercial moisture control system employing the principles developed by the Stoneville Laboratory. The system was found to have wide fluctuations in the input temperature. This was called to the manufacturer's attention and the systems are being modified to correct this discrepancy.

An evaluation was made at Stoneville of a new portable cotton moisture meter. On the basis of these tests the manufacturer is modifying the design and changing the meter scale to show wet basis moisture content.

C. Seed Cotton Cleaning

1. A study at Stoneville of the cleaning efficiency of individual seed cotton cleaning machines at various rates of feed and seed cotton moisture contents showed that cleaning efficiency increased as moisture content

decreased. Also, cleaning efficiency, as measured by the Shirley Analyzer, decreased as the rate of feed increased, although these differences were not always reflected in classers grade. Spinning performance was affected as would be expected by reduced moisture content but not by variations in the rate of feed.

The recommended cleaning machinery arrangement for machine-picked cotton was found to be adequate for ground-gleaned cotton in the Stoneville area. More elaborate cleaning removed more foreign matter but it was not reflected in classers grade due to the reduction of color caused by weather damage.

A device for the removal of large foreign matter such as stalks and limbs from seed cotton was developed at Stoneville. It is not intended for use on cotton containing only small trash. Drawings have been turned over to the gin machinery manufacturers and others and some plan to incorporate the principle into existing machines.

Test lots of seed cotton containing 0 to 100 percent tight locks, in 10 percent increments, were prepared and ginned on an 8-saw laboratory gin at Clemson. Fiber, seed, and spinning tests are being made to provide data for computing linear regression coefficients and prediction equations, and making graphical representations of the findings. Total linear regression from 100 percent fluffy locks to 100 percent tight locks was as follows:

Lint percent turnout -- 7.6 percentage points, from 39.2 to 31.6 percent
Micronaire reading -- 1.11, from 3.59 to 2.48
Colorimeter reflectance, R_d -- 19.6, from 74.2 to 54.6
Colorimeter yellowness, $+b$ -- 3.5, from 8.0 to 11.5
Grade equivalent, colorimeter -- from SLM to SGO yellow tinged

These results show trends in degradation of fiber quality in relation to the proportion of field degraded tight locks in the seed cotton. These data show close agreement with a preliminary scale of fiber quality for field degraded cotton which was developed last year.

Evaluation tests were made at Clemson for the fourth year on an experimental drum-type tight lock separator and an auger-type separator. Again this year, bale value increases by removing the tight locks from the cotton were less than \$5 per bale. Measurements of fiber properties were found to be relatively insensitive to changes in tight lock content, particularly with the low incidence of tight locks in the cotton available during the development of this equipment. No further development and testing of the separators is planned; however, they will be retained on a standby basis in anticipation of seasons of higher field degradation, which have occurred in the past. The separators have been and will continue to be used to separate tight locks for setting up scales of fiber quality and spinning performance for cottons containing from 0 to 100 percent tight locks in 10 percent increments. This indirect approach should provide a better indication of the advisability of tight lock removal prior to ginning than comparison of

grade, staple, and fiber properties of uncontrolled lots of cotton processed with and without the lock separator.

Analysis of trash made at Clemson showed that bur size varied among varieties and seasons of growth and that sticks in all cottons analyzed ranged from 1 to 2 inches in length irrespective of type of harvest. The number of sticks in machine-picked cotton was about three times the amount found in hand-harvested material. Machine-stripped cotton contained eight to nine times the amount found in hand-harvested material.

D. Conveying

1. At Mesilla Park effort was concentrated on an air-jet conveyor system which shows considerable promise for adaptation to all materials handling problems in the gin in addition to seed cotton. Conveyor capacity rates for various air volumes at the horizontal and at various inclined positions were studied. The tests showed the air-jet conveyor to have potentially sufficient capacity to meet the requirements of modern high-capacity plants. Further, the tests showed the air-jet conveyor to be much more efficient than conventional methods.

E. Gin Stands

1. Saw Gins

Research at Stoneville shows that the use of reduced diameter saws is poor economy in today's high-capacity gins. A reduction of 1/16-inch in saw diameter due to repunching resulted in a 10 percent reduction in ginning rate, a 10 percent increase in energy requirements, and a 1 percent increase in seed linters content.

A device which recently came on the market to change the profile of a low-capacity gin stand roll box was tested at Stoneville. The device gave an increase in capacity of 16.4 percent in a 12-inch 80-saw stand. Significant increases in power and energy requirements and residual linters were noted when the device was used. There was a very slight reduction in upper quartile and mean fiber lengths associated with the use of the device.

2. Roller Gins

At Mesilla Park a conventional roller gin feeder was modified to eliminate the feeder apron and to allow the final doffer brush in the feeder to present the cotton in a single lock form directly to the ginning point of the gin stand. This modification eliminates the difficulty experienced with static on the lint slide, gives a more even feed of cotton to the gin, thus increasing capacity and reducing the amount of seed cotton which must be reclaimed from the seed system. Because of a more even distribution of cotton on the roll, it ran cooler which prolonged its life and thereby reduced maintenance cost.

Tests of pressure of the stationary knife against the ginning roll in combination with roll speed showed that capacity was increased from 12.1 to 19.4 pounds per inch of roll per hour for Pima and from 8.8 to 12.8 for Acala 1517 when roll speed was increased from 80 to 100 r.p.m. and knife pressure increased from 75 to 110 pounds per square inch of gage pressure. The gin roller surface temperature ranged from 88° F. at 80 r.p.m. to 132° F. for 100 r.p.m.

Studies of the effect of roller speed and rotary knife pressure showed that with Pima cotton 9.0 pounds of lint per inch of roller per hour was obtained at 80 r.p.m. and 75 p.s.i. gage pressure on the knife as compared to 25.3 pounds per inch per hour at 140 p.s.i. knife pressure. Acala 1517 cotton was ginned at a rate of 6.4 pounds per inch per hour at 50 r.p.m. and 85 p.s.i. gage pressure as opposed to 18.8 pounds at a roll speed of 160 r.p.m. and 110 p.s.i. gage pressure. The high rates correspond to two bales of Pima per hour and one and one-half bales of Acala 1517 per hour for a gin stand having a standard width of 40 inches.

At Mesilla Park studies were made of adjustments of a new type high capacity roller gin stand using Acala 1517 cotton. Three mechanical adjustments were studied: (1) The clearance between the rotary and stationary knives; (2) the position of the rotary knife parallel to the stationary knife; and (3) the angular position of the stationary knife with respect to the roller surface. It was found that the knife-to-knife clearance must be maintained between 0.030 and 0.040 inch. Increasing the clearance caused a decrease in ginning rate and decreasing the clearance resulted in the possibility of collision between and breakage of the knives. Changing the rotary knife position parallel to the stationary knife had little effect over the range studied. The angular position of the stationary knife with respect to the roller surface was studied over only a small range, presently limited by the construction of the gin stand. Increasing the tilt of the knife away from the roller surface increased ginning rate, produced less neps in the ginned lint and ginned less linters from the seed, all desirable changes. These studies will be continued using both the McCarthy and the new high-speed rotary-knife roller gin stands.

F. Gin Performance and Cotton Quality

1. Power requirements and efficiency. In cooperation with the Economics Research Service, power and energy data were collected at 11 high-capacity gin plants in California and West Texas. Power requirements for operating the California plants averaged 650.8 horsepower. The Texas plants required 638.5 horsepower. Energy consumption was calculated to be 48.3 and 45.9 kw.-hr. per bale for the California and West Texas gins, respectively. Slightly higher connected loads were noted for the West Texas plants, while idle loads were slightly higher for the California plants.

Studies in the Mississippi Delta area showed that per bale energy requirements for pressing ranged from .38 to .52 kw.-hr. per bale. The studies also showed that mechanical tramping is by far more economical than hydraulic.

At Clemson efficiency studies were conducted at six commercial gins in the Coastal Plain area of South Carolina to study and evaluate operational efficiency of equipment and techniques employed at commercial gins and power requirements for operating gin machinery. Five of the six were high-capacity plants, representing each of the five major gin machinery manufacturers. The sixth gin was an older style low-capacity plant.

Total connected electrical load ranged from 370 to 666 horsepower rated capacity from 6 to 14 bales per hour and electrical load per bale rated capacity from 41.1 to 63.3 horsepower. Electrical load per bale rated capacity, reflecting plant design efficiency, was highest at the low capacity plant.

Power consumption ranged from 33.8 to 70.8 kw.-hrs. per 500 pound gross weight bale.

Plant operational efficiency, ranging from 52 to 96 percent, was affected by practices utilized both within the gin and on the gin yard and by conditions existing at each gin. Some practices resulted from imposed conditions over which the ginner had little or no control.

Practices and conditions within the gin which contributed to idle operating time or resulted in a decreased ginning rate were the major factors adversely affecting plant operational efficiency. Plant efficiency was highest at those gins utilizing practices to minimize idle operating time.

The manner in which seed cotton was delivered to the gin imposed conditions which influenced gin yard practices. One-bale loads, seed cotton all or partially in sheets, and single axle trailers increased personnel requirements, created additional problems on the gin yard, and magnified the effects of inefficient practices within the gin. Generally, power consumption per bale increased as the amount of seed cotton in sheets and one-bale loads increased. Plant operational efficiency increased when practices, designed to minimize the effects of imposed conditions, were adopted.

Based on the results of this study, conclusions in the form of general recommendations for more efficient gin plant operation and reduction of power requirements were developed and published.

2. Quality evaluation. As a matter of routine all samples of lint ginned in connection with the research program at Mesilla Park are subjected to scanning with ultraviolet light and to relate any fluorescence to its cause and fiber quality irregularities.

At Mesilla Park two instruments for measuring tenacity of seed cotton were evaluated. A statistical analysis of over 1,200 measurements using a 1/8-inch spacer in the seed cotton clamps favored a modified Scott Tester over a modified Hunter Terminal Pull Tester.

Five experimental methods for rapidly determining the amount of linters in cottonseed as an index of ginning performance were investigated at Mesilla Park. Preliminary results show that a visual grading system may prove to be sufficiently accurate and of more practical value than other methods tested.

Studies at Mesilla Park as to how neps are formed showed that saw ginned samples averaged eight to nine neps while the roller ginned control averaged three to four. There was no statistical difference between the nep counts of cotton ginned at a saw speed of 300 and 600 r.p.m.

A survey of five high capacity and three conventional roller gins was made in the Mesilla Valley on both long staple and upland cotton. With each type cotton, the high capacity gins ginned at greater average rates than did the conventional gins; with upland, 5.43 vs. 2.22 lbs./in. roll/hr.; and with Pima, 6.66 vs. 3.68 lbs. The high capacity gins averaged very slightly more seedcoat fragments, but the fragments were reduced by mill-type lint cleaners. Cottonseed and fiber qualities were similar for the two types of gins; except array measurements showed the lint, both upland and Pima, from the high capacity gins had greater mean lengths and fewer short fibers than did the conventional roller gins.

Comparisons between methods of determining cottonseed moisture content were made at Mesilla Park. This work included experimental wire baskets versus conventional aluminum cups, with and without forced draft in the oven, and the times of 1 hour versus a weekend of storage of oven-dried samples in a desiccator. The conventional method with aluminum cups required much less time than the larger basket to obtain the same results. The forced draft in the oven was found to be necessary, and a weekend of storage of oven-dried samples in the desiccator did not affect the moisture content.

The problem of preginned lint lost in seed cotton cleaner waste was investigated at Mesilla Park. Lint recovered from this waste was subjected to no drying and excessive drying (300° F.) and excessive cleaning (bur machine and stick remover in addition to a 6-cylinder cleaner) while ginning Pima S-1 and S-2. The recovered preginned lint weighed only from 1 to 6 grams per 1,000 pounds of seed cotton. The preginned lint was inferior to the ginned lint in fiber length, length distribution, short fibers, micronaire, and strength. The measured small quantity and inferior qualities of the preginned lint make them appear unimportant. No future research in this field is planned.

A wettability test under development at Clemson shows promise as a quick means for quality evaluation in ginning research. In this test a lint sample is dropped on the surface of an alcohol-water mixture and the submergence time is recorded.

Sample preparation has been found to be a critical factor and efforts this year were devoted to elimination of variation attributable to sample preparation techniques. Equipment was constructed for increasing compaction of the sample plug, thus resulting in a more uniform sample density.

At Clemson a Shirley Analyzer was used in destructive lint tests to magnify differences in fiber qualities which exist following ginning treatments, and then to correlate these differences with spinning performance.

Fiber qualities changed progressively during five passes through the Shirley Analyzer but the progression was not linear. Generally the first pass resulted in the greatest change, giving a hyperbolic curve.

Noteworthy trends and consistency were apparent in short fiber content and other length measurements; however, moisture regain, strength, and elongation measurements showed some inconsistency.

Correlation between yarn strength and fiber measurements was generally higher for micronaire and length measurements than for other fiber evaluations.

The effect of destructive lint tests on length measurements appears to be good indicators of yarn strength. Coefficients of correlation between yarn strength and Fibrograph UHML of lint which had been through the Shirley Analyzer 0, 1, 2, 3, 4, and 5 passes were 0.913, 0.953, 0.967, 0.975, 0.996, and 0.969, respectively.

Also at Clemson a photographer's exposure meter was used in developing an instrument evaluation of cotton fluorescence under ultraviolet light. Variations in intensity of fluorescence were detected with the meter in a test box under two long wave 4-watt lamps (3,660 angstrom units).

At Stoneville an effort was made to measure foreign matter components in lint cotton using one and two screens in the Shirley Analyzer trash pan. A 1/8-inch mesh screen was located 1/2 inch from the bottom of the trash pan and a 1/4-inch mesh screen was located 1-1/2 inches from the bottom. The tests show that for samples with a wide range of foreign matter, the material on the 1/4-inch screen and in the trash pan increased as the total waste increased, while the material on the 1/8-inch screen did not consistently increase as total waste increased. Use of the 1/4-inch screen in the trash pan is a valuable aid in picking up the lint and foreign matter for rerunning through the machine. On the basis of tests performed, two screens in the Shirley Analyzer trash pan can be used to analyze visible waste by size in lint samples.

In the tests at Stoneville aimed at improving the accuracy of the Shirley Analyzer results it was found that the average amount of second-pass visible waste on samples with a wide range of foreign matter was 10.5 percent of the first-pass total waste and 15 percent of the first-pass visible waste. When the foreign matter and lint in the trash pan are passed three times through the machine the total waste correction is 11.5 percent and the visible waste correction is changed to 14.5 percent. The accuracy of the one-pass method of testing is improved by using these correction percentages.

In other tests it was found that lint foreign matter testing time could be decreased from 5 to 3 minutes by increasing saw cylinder, feed roll, and condenser speeds 60 percent and the fan speed 6 percent.

Also at Stoneville a Shirley Analyzer procedure was worked out for determining the amount of seedcoat and funiculi in lint cotton. The test is much faster than the ASTM method but is not as accurate. However, it is suitable for screening samples. The procedure involves the use of 3 screens, 1/4-inch, 1/8-inch, and 1/16-inch mesh in the Shirley Analyzer trash pan and 10-gram test specimens. Testing time is 5 minutes as compared to 30 for the ASTM test procedure.

A formula was developed at Stoneville for obtaining cottonseed moisture percentages after 3 hours' drying. Calculated percentages did not differ from the regular 5-hour drying method percentages more than those found for two specimens taken from the sample container and tested by the regular 5-hour method.

The Mesilla Park Fiber Sorter gave good results when the data from 48 ginning test samples were compared with long and short fiber measurements made with the Suter-Webb Sorter.

In an effort to develop a rapid method for determining the amount of short fibers in a lint sample, tests were made at Stoneville using compressed air. Results closest to those from the standard array procedure were obtained using two 6-inch vise grips with a space of 7/16-inch between the vise grips clamping the fiber and an air pressure of 80 p.s.i. with a nozzle held 1/2 inch from the fiber. Averages for three tests on each of three check samples were not as good as desired, but more tests with changes in clamp holding surfaces and nozzle dimensions should give more accurate values.

The ASTM Differential Dye Test was found to be unsuitable for general use as an indicator of gin damage to cotton.

Tests at Stoneville show that a Ginning Laboratory designed, 3-level, constant-humidity cabinet was found to be an excellent tool for providing test specimens of highly uniform moisture content. A determination of equilibrium moisture content at 5 r.h. levels on lint preconditioned wet and preconditioned dry showed that similar cottons of different histories

can differ in equilibrium moisture content by as much as 1-1/2 percentage points at Mid-South ambient atmospheric conditions and at standard atmosphere for testing. Thus it is important that other methods of moisture determination (such as gravimetric) be used when correlating fiber properties to fiber moisture content.

At Mesilla Park small lots of Acala 4-42 and Pima S-2 seed cotton were treated to compare the effects of single-locking and mass-locking on ginning capacity and turnout. Single-locking was accomplished by separating individual seed cotton units by hand, with efforts to maintain the same original foreign matter and moisture contents. In the conditioned laboratory, 65 percent r.h. and 70° F., three replications of the upland were saw ginned and three replications of the Pima were roller ginned.

The Acala 4-42 ginned at a slightly faster rate when single-locked than when mass-locked (2.85 versus 2.65 lbs./saw/hr.), and the turnout was similar for the two treatments (39.0 and 38.8 respectively).

The Pima S-2 also ginned at a slightly faster rate when single-locked than when mass-locked (1.47 versus 1.41 lbs./in./hr.), and the turnout was practically the same for the two treatments (40.9 and 40.8, respectively). These preliminary tests, with single-locking of both upland and Pima, accomplished by hand to minimize changes in foreign matter and moisture contents, indicate that single-locking of seed cotton might be slightly superior to mass-locking in the effects on ginning capacity and turnout.

3. Effect of Cultural and Harvesting Practices. Tests at Mesilla Park show that spindle twists are a serious problem in roller ginning. Studies of what type of seed cotton cleaning principle was most efficient in removing them revealed that the "sling-off" principle of the stick machine showed the most promise and will be subjected to further tests.

In cooperative tests with the Cotton Mechanization group at Stoneville, six varieties of cotton with widely different stalk and boll characteristics were compared with respect to picking efficiency, trash content, response to cleaning and ginning, preharvest loss, and yield. Conditions were more uniform and picking efficiencies and yields were higher than in previous years. More trash was harvested with the Stoneville 7-A than the other five varieties. Delfos 9169 had the highest yield. However, there was no significant difference between the yields of Delfos 9169, Stoneville 7-A, D&PL Smoothleaf, and Lankart 57. Delfos 9169 had the highest picker efficiency. This was an excellent harvesting year and preharvest losses were very low.

There was some tendency shown toward a relationship between the average peak force required to remove a lock of cotton, the carpel angle, and the picker efficiency. Lankart 57 required the most force with an average of 162 grams, while Stoneville 7-A required the least force with an average of 70.7 grams.

Seed cotton lots representing three replications of the six varieties were cleaned and ginned in the Micro gin with a machinery arrangement normally recommended for machine-picked cotton in the Mid-South area.

There were no important differences in grade values even though Lankart 57 had a higher lint foreign matter content than the other five varieties. Acala 4-42 and Delfos 9169 had grade index values of 99.0 as compared to 100.0 for the other four varieties. The average staple and fibrograph span length of Delfos 9169 was higher than for the other five varieties. Fiber strength (zero gage) ranged from a high of 87.0 (1,000 p.s.i.) for Acala 4-42 down to 75.7 for Lankart 57 and Delfos 9169.

A second cooperative test at Stoneville involved topping rank-growing Stoneville 7-A cotton plants on three different dates (July 20, August 5, and August 20) and trimming lateral branches just as they began to lap in the row middle (July 24) had no effect on seed cotton yield, lint grade, staple length or picking efficiency. There was slightly less foreign matter in the machine-harvested seed cotton and lint from the topped and laterally trimmed plots than from the untreated plants, although no important differences were obtained among the topped and trimmed treatments. Boll rot loss was reduced slightly by early topping (July 20) in an area where the average boll rot loss was less than five percent. Although plant lodging, as well as boll rot, was not a problem in this area in 1964, it was observed that plants in the topped plots were more erect.

The harvested lots of seed cotton were processed in four replications in the Micro gin. The recommended ginning arrangement for machine-picked cotton was used.

Grade for all lots and treatments was Middling, and all cotton samples classed 1-1/16 inch in staple length.

Tests conducted at the Southeastern Cotton Ginning Research Laboratory in cooperation with Clemson University Agricultural Engineering Department indicate weed control practices affect lint grade and value.

Four field treatments were as follows:

1. Treflan-Mechanical
2. Treflan-Mechanical-Flame
3. Karmex-(applied in band) Mechanical-Flame
4. Herban-Dicryl DSMA-Flame

Visible waste in lint of treatment 4 was significantly greater than that of all other treatments and total waste in lint of treatment 4 was greater than that of treatment 2.

Wagon grass content of treatment 4 averaged 1.18 percent compared to less than 0.12 percent for other treatments. This grass content was reflected in grade reductions assessed all samples from treatment 4, one-half of which were reduced two full grades.

All treatments, except treatment 2, had at least one classers sample reduced in grade because of grass.

Grade index and per pound lint value of treatments 2 and 1, after reductions due to grass, were significantly higher than that of treatment 4.

Though not significant, lint from treatment 4 had the highest picker card waste and the lowest strength 1/8-inch gage, average break factor, 2.5 percent span length and color factors.

Results of all factors measured indicate that treatments 2 and 3 produced the most desirable results and treatment 4 the least desirable.

At Clemson a study was made to compare the ginning performance, fiber qualities, and spinning performance of spindle-picked and stripper-harvested cotton, and to evaluate seed cotton conditioning and cleaning treatments for processing cotton harvested by the two methods. This study was in cooperation with the pilot spinning plant and the mechanization group of ARS.

Returns per acre were \$42.78 more for the stripper cotton than for the picker, based on gross value of the lint and seed. Yields per acre were 2.13 bales with the stripper and 1.76 bales with the picker. Harvesting and ginning costs were not specifically evaluated. Grade index averaged 94 for the picker and 83 for the stripper, with the lower value for the stripper due primarily to grass content. Staple lengths were practically the same, averaging 33.7 (32nds inch) for the picker and 34.0 for the stripper.

Other significant comparisons between the picker and stripper, respectively, were: Wagon sample trash content, 3.6 percent versus 25.5 percent; feeder sample trash content 0.9 percent versus 4.1 percent; lint foreign matter, 3.2 percent versus 4.9 percent; colorimeter yellowness, 8.4 versus 7.7; CCC price per pound, 30.29 cents versus 27.92 cents; ginning rate, 8.5 lbs./saw/hr. versus 6.7; and total trash removal per bale, 72.5 lbs. versus 534.5 lbs.

Ginning treatments included three seed cotton cleaning arrangements: (1) Conventional setup for machine-picked cotton, (2) same machinery but with stick and green leaf machine placed following first drier, and (3) same as No. 1, but with stick machine following last cleaner. All cotton was processed through two lint cleaners, and driers were set to maintain 6 percent lint moisture at the ginning point. In analyzing the ginning treatments, the only significant difference was in lint value. The price per pound averaged 43 points less for the setup with the stick machine placed last when compared with the average of the other two treatments.

Tests were made at Mesilla Park of the ginning characteristics of various new strains of cotton being developed for various parts of the Southwest.

Completed measurements on the 1963 crop of five upland strains showed that Strains Nos. 6612 and 8229 compared at least favorably in capacity, turnout, length and all other qualities with the standard variety, 1517D, grown in that area. Generally, with this group of strains, the higher ginning capacities are associated with lower tenacity, fewer cottonseed linters, fewer short fibers, and greater seed index. Number 6612 was released as 1517V for production on Verticillium wilt infested soils.

The five strains in the 1964 crop included Strain No. 4447, formerly Hopi Acala, and recently released for production in Arizona as Hopicala. Since it does not have quite the staple length of 1517D, it was not released for production in New Mexico and Texas. A few small tests show that Hopicala gins at about the same capacity as 1517D. Quality measurements for tenacity, cottonseed, and fibers are not complete. The seeds of Hopicala appear relatively fuzzy. No major problem is anticipated in ginning Hopicala, but present plans are to continue research with this new variety, both with small lots of cotton in the laboratory and with observations and sampling of commercial gins in Arizona.

Completed measurements for the 1963 crop of four Pima strains (S-1, S-2, E1044, and P14) showed that E1044 had ginning and quality characteristics similar or only slightly better than the old S-1, but the E1044 had longer fibers. Incompleted measurements for the 1964 crop of six strains at two locations showed again that the E1044 ginned at a rate only slightly better than S-1, and was surpassed by the other strains at both locations (Tempe and Safford). As a result of the longer fibers of the E1044 than either S-1 or S-2, this new strain is being increased for possible release in locations of high elevation such as the Mesilla and El Paso Valleys. The cooperating breeder is considering the release of more than one strain for the different elevations in the areas of Pima production. The 1964 strains include P15 and P17, either of which might be released for production at the lower elevations. These two strains ginned at better rates than did the E1044 or S-1, but not quite as well as S-2.

Among the completed measurements of the 1963 strains, greater ginning capacity appears to be associated with greater turnout, lower tenacity, and lower cottonseed linters contents.

G. Lint Cleaning

1. A study at Stoneville of the effect of lint cleaning on cotton quality at various lint moisture levels indicated that increases in the fiber moisture content at lint cleaning decreases the cleaning efficiency of the lint cleaners, and increasing the number of lint cleaners decreases the foreign matter content of the lint in a curvilinear relationship.

Increases in the classers grade index is directly related to decreases in the fiber moisture content at lint cleaning and to the number of lint cleaners, while increasing the fiber moisture content and decreasing the lint cleaner stages gave an increase in the classers staple length. For maximum foreign matter removal commensurate with minimized changes in classers staple length, a moisture range of about 7.0 percent gave the best results.

Decreases in the 2.5 percent span length and 50 percent span length are related to decreases in the fiber moisture content at lint cleaning and to increases in number of lint cleaners. Fifty percent span length data show an unacceptable amount of fiber breakage with three and four lint cleaners at any moisture level, and show an unacceptable amount of breakage with one and two lint cleaners at fiber moisture of five percent and below. Number of neps per 100 square inch of web increased with added lint cleaners, but showed essentially no difference due to changes in fiber moisture content.

H. Packaging

1. Two experimental packaging materials were evaluated at Stoneville for the National Cotton Council.

Assistance was given in developing USDA Standard for Jute Bagging. These standards have been published in the Federal Register.

Studies underway on new packaging methods at Stoneville indicate that a round "picker lap type" bale may be mechanically feasible for gins. Preliminary tests indicate that if such a packaging system can be developed labor may be reduced 50 percent and power 80 percent.

I. Cottonseed

1. A device initially designed in 1962 for the removal of cockleburrs from cottonseed was fabricated and subjected to experimental testing at Stoneville.

First-cut and second-cut cottonseed and corresponding first-cut and second-cut cockleburrs were used, with the machine operated at various angles of incline, feeds, speeds, etc.

It was found best to use first-cut delinted seed in the machine, and with the best selected operating conditions the device proved to be effective to the extent of removing 50 percent of cockleburrs from the first-cut cottonseed. While this is a help, it is not considered good enough to justify an enthusiastic recommendation of the device for use in the cottonseed industry.

Investigations designed to determine the degree to which cottonseed are mechanically damaged during the ginning process were carried on by the Stoneville Laboratory. These studies were conducted in five commercial gin plants in the Imperial Valley of California during the 1964 ginning season. Results of these tests indicate an average of 10.7 percent damage resulting from both harvesting and ginning. The ginning process accounted for 5.7 percent of this damage. Test data also indicated that gin stand damage will also increase with some of the new type high-capacity gin stands. In general, increased gin stand damage was also noted at higher seed moisture contents and seed indexes. Tests are now being made to determine the effect of mechanical damage on seed germination.

Studies were also made to study the effect of varying ginning rates on cottonseed quality. Results of these studies conducted on a new type, high-capacity gin stand indicated that increases in ginning rates will cause accompanying increases in seed damage. For ginning rates ranging from approximately 10 to 23 pounds of lint per saw per hour, seed damage increased from 19 to 33 percent. Average germination results, from the three test series involving five bales each of early, mid, and late season cottons, indicated a 3.5 percent reduction in germination resulting from ginning.

Increases in abnormal and secondary root seedlings were also noted as a result of gin processing. The presence of seedcoat fragments in lint samples also increased as ginning rates were increased.

Tests at Clemson also showed that the average seed damage generally was greater in high-capacity gins than in the control gin.

Seed germination values were unusually low throughout the state this year and seed quality values in this study were inconsistent as well. For the control gin, the percent abnormalities counted in the germination lots were slightly higher than the average for the high-capacity gins. Seedcoat fragments were also higher for the control gin.

The percent residual linters averaged higher for the high-capacity gin than for the control gin.

J. Waste Collection and Disposal

1. Tests were made by the Mesilla Park Laboratory to check the design of high-capacity inline air filters to handle large volumes of air. One was designed to filter 20,000 cubic feet of air per minute and was installed at a local gin plant on a large battery-type condenser exhaust. Another filter was installed at a gin plant near Lubbock, Texas. It was designed to handle 10,000 cubic feet of air per minute. Both filter units performed satisfactorily throughout the entire ginning season. These tests showed that the large inline air filters for battery-type condenser exhausts could be properly sized by using the Laboratory's design procedure.

A large centralized air filtering system was installed at the Dona Ana Gin Company's roller gin at Dona Ana, New Mexico. This large filter unit, sized to handle 33,000 cubic feet of air per minute, was placed in the end wall of a 10-foot by 20-foot dust house attached to the main gin building. Four condenser exhausts discharged dust and lint laden air into the dust house. This polluted air was then cleaned as it passed through the wall filter on its way to the outside. While mechanical difficulties prevented a complete season's testing of the system, it did operate long enough to show that the centralized filtering concept was feasible but that better mechanical design was needed. This type of filtering system would be particularly attractive when a number of exhausts exit from the gin building at a central location.

Studies at Clemson indicate that wet operation of an experimental inertial separation chamber was more effective in removal of dust and other particulate matter than was dry operation.

Air from the unloading separator was exhausted into the chamber to provide a source of dust-laden air relatively free of large trash particles. Chamber design limited flow of air to approximately 7.0 feet per second. Only the larger and heavier trash particles were removed in the chamber during dry operation and considerable dust and fly lint was observed near the chamber exhaust.

For wet operation nine spray nozzles, located in the first two chamber sections, injected approximately 70 gallons of water per hour at 80 p.s.i. Only occasional particles of trash were observed emerging from the chamber exhaust during wet operation. Dust concentration at chamber exhaust while operating dry averaged 0.1412 and 0.6550 grams/1,000 feet for late season machine-picked and machine-stripped cottons respectively. With addition of water spray to the chamber, dust concentration was reduced to 0.0379 and 0.1811 grams/1,000 cubic feet for late season machine-picked and machine-stripped cottons respectively. Wet operation decreased dust concentrations by approximately 73 percent.

Tests at Stoneville show that lint fly from the exhaust of low-pressure condenser fans can be eliminated at the condenser by using fine meshed screen or perforated sheet metal for drum covering. This can be done without detrimental effect on the quality of the lint.

The Stoneville Laboratory and the Economic Research Service initiated cooperative studies aimed at the development and evaluation of a new and better method for reclaiming and cleaning gin-loss cotton. These studies resulted in the development of a machine for reclaiming usable fibers from gin-loss material.

Test evaluations of the machine indicated that approximately 72 percent of the usable fibers present in gin-loss cotton could be reclaimed with only one processing. Average cleaning efficiency for the reclaiming device was 84.3

percent. Tests also indicated that length distribution of the gin-loss fibers was slightly improved as a result of processing. Spinning tests indicated that it is feasible to spin a mix consisting of 100 percent reclaimed fibers. Although manufacturing waste was high and yarn strength and appearance relatively low when only reclaimed fibers were used, they should perform satisfactorily in mixes used to manufacture certain low-count yarns and fabric constructions.

Buyers offered an average of 1.5 cents per pound for gin-loss cotton before processing, and 6.67 cents per pound after processing. Based on these prices, and after adjustment for weight loss bale value was increased over \$5 per bale by one pass through the reclaiming facility. Under current price relationships and market outlets, it is not profitable to pass gin-loss cotton through the reclaimer more than one time.

Feasibility of blending reclaimed gin-loss fibers into the bale from which they originated was also investigated. At blending rates averaging 8.5 pounds of reclaimed fiber per bale, no important differences were noted in grade, staple length, fiber properties, and spinning performance between blended and non-blended cottons. Based on current market prices, bale value was increased by \$2.69 as a result of the blending operation.

Based on results obtained from these studies, reclaiming of gin-loss cotton by methods described in this report is an entirely feasible and profitable practice for use in cotton ginning systems. The increase in overall quality of gin-loss cotton resulting from the reclaiming process would make the material much more competitive in the cotton waste industry. No definite conclusions were reached regarding the blending of gin-loss fibers back into a gin bale due to the limited scope of these studies. Large scale spinning tests are planned for further evaluation.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

BASIC AND EXPLORATORY INVESTIGATIONS

Southern Utilization Research and Development Division, ARS

Problem. Cotton, the nation's most important fiber, is facing severe and increasing competition from synthetic fibers. Cotton is America's largest source of cash farm income and still accounts for more than half of the total U. S. mill consumption of all major fibers. However, its proportionate share of the market has been slowly decreasing as has the per capita consumption. The rapid growth of the synthetics at the expense of the natural fibers has been a phenomenon of the century. Expansion of market outlets for the chemical fibers has been based on vigorous research and development programs. The engineering and development programs of the chemical fiber industry are designed to capitalize on the special properties of each individual fiber as related to the functional use qualities desired in particular products; basically they involve the substitution of the newer fibers for cotton in cotton's traditional end-use markets. Expanded research to increase the utilization potential of cotton offers the most realistic opportunity for improving cotton's competitive strength as a textile fiber and for increasing cotton consumption. Basic and exploratory investigations, studies on interrelations among fiber, yarn, and fabric properties, new and improved textile machinery, improvement of wash-wear properties and improved cotton properties and products are basic to holding existing markets or expanding the use of cotton in new applications.

Fundamental information is badly needed in applied research to help cotton gain new and maintain old markets. Fundamental knowledge of the cotton fiber as to its structure, properties, and the mechanisms involved in chemical and physical behavior serves as a basis and a guide in the design and improvement of processing machinery, mechanical and chemical processes, and in the development of new and improved cotton yarns, fabrics, finishes, and treatments. Many chemical and physical treatments, as well as textile organizations and machine designs, offer a basis for the improvement of cotton quality or lowering of processing costs. Exploratory chemical and physical research is needed to determine the true potential of such approaches prior to undertaking extensive developmental research or the construction of prototype machinery. Specific areas in which basic information is needed include the chemical properties and structure of native and modified cottons; the chemical modification of cotton cellulose; chemical reactions induced in cotton cellulose by high energy radiation; reaction mechanisms, rates, and catalysis of cotton cellulose reactions; new concepts and methods for evaluating the physical properties of native and modified cottons; relationships of the structural arrangements within cotton fibers to the physical properties of native and modified cottons; mechanisms of physical damage to cotton due to mechanical, chemical, or biological actions; fine structural changes occurring during chemical and physical modification of cotton cellulose; and correlations of the fine structure of cotton fibers with their gross behavior in textile structures.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, analytical chemists, physical chemists, physicists, microscopists, chemical engineers, statisticians, mathematicians, cotton technologists and textile technologists engaged in basic and exploratory studies to develop fundamental information needed in applied research to help cotton gain new and maintain old markets.

Basic research on the structure of cotton fiber and its relation to the behavior in mechanical and chemical treatments, essential to an understanding of the performance of fibers during processing and in textile products, is carried out at the Southern Regional Research Laboratory, New Orleans, Louisiana. Included is the research of the Plant Fibers Pioneering Research Laboratory to obtain basic information on the supermolecular structure of plant textile fibers; and to relate information of polymer and fiber structure to the mechanical and textile behavior of fibers. Additional basic research on chemical and physical properties and structure of cotton is being carried out: (1) under contract at Stanford Research Institute, South Pasadena, California, on determination of the structural components of the cotton fiber that contribute most to tensile strength and how they can be utilized to increase tensile and recovery properties; at Texas Agricultural Experiment Station, College Station, Texas, on the effect of variation in structure on cotton fiber properties caused by environmental and genetic factors; at the University of Tennessee, Knoxville, Tennessee, on investigations to determine the effects of fiber extensibility on fiber breakage in mechanical processing; at the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., on relationship of molecular size, nature, shape, conformation, and configuration of organic non-aqueous compounds to their swelling power on cotton cellulose; and at Harris Research Laboratories, Inc., Washington, D. C., on investigation of factors influencing comfort in cotton apparel fabrics; and (2) under grants at Massachusetts Institute of Technology, Cambridge, Massachusetts, on investigation of fiber and yarn geometry in areas of deformation in cotton fabrics; and at Georgia Tech Research Institute, Atlanta, Georgia, on elucidation of the role of fiber morphology on frictional behavior.

Exploratory chemical and physical research is also conducted at New Orleans, Louisiana, as a basis for the improvement of mechanical and chemical processing, and in the development of new and improved yarns, fabrics, finishes, and treatments. One phase of the research -- exploratory investigation of reversible chemical reactions to obtain information basic to the development of a commercially feasible reversible crosslink -- is conducted with cooperation and support by the Cotton Producers Institute. The International Lead Zinc Research Organization cooperates in and supports exploratory research to impart useful properties to cotton through application of lead, zinc, and other metal compounds. Additional exploratory chemical and physical investigations are also being carried out: (1) under contract at Macrosonics Corporation, Carteret, New Jersey, on

treatment of cotton fibers with acoustic energy; at Gagliardi Research Corporation, East Greenwich, Rhode Island, on chemical modification of cotton through treatments with reagents in the vapor phase; at Harris Research Laboratories, Inc., Washington, D. C., on the development of finishes for cotton fabrics to render them more rapid drying; and (2) under a grant at Textile Research Institute, Princeton, New Jersey, on crosslinking of chemically modified cotton to obtain cotton fabrics with an optimum combination of resilience and thermoplasticity.

Other research on chemical and physical properties and structure of cotton is in progress under grants of P. L. 480 funds to the following foreign institutions: National Institute of Applied Chemical Research, Paris, France, for a fundamental study of the relation of crystallinity to accessibility in cottons (project duration - 5 yrs.); Swedish Institute for Textile Research, Gothenburg, Sweden, for an investigation of setting reactions in cotton fabrics (project duration - 5 yrs.); Central Laboratory, T.N.O., Delft, Holland, for a fundamental study of the response of cotton fiber structural elements to stress (project duration - 3 yrs.); Fiber Research Institute, T.N.O., Delft, Holland, for an investigation of the fundamental mechanisms and bonding forces that could be used to improve tensile strength and other physical properties of cotton textiles (project duration - 5 yrs.); Ahmedabad Textile Industry's Research Association, Navrangpura, Ahmedabad, India, for a study of the relation between the fine structure and mechanical properties of cotton fibers by swelling and stretching treatments (project duration - 5 yrs.); and for a study of the physical chemistry and thermodynamics of solution and vapor phase adsorption on and in the cotton fiber (project duration - 5 yrs.); University of Bombay, Bombay, India, for an investigation of the photochemical degradation of cotton (project duration - 5 yrs.); and for an investigation of new solvents for molecular weight determination of cellulose (project duration - 3 yrs.); Indian Central Cotton Committee, Bombay, India, for investigation of the microbial decomposition of cellulose with special reference to the effect of Indian bacterial organisms on cotton and cotton fabrics (project duration - 4 yrs.); Juan de la Cierva School of Technical Investigations, Barcelona, Spain, for a study of the measurement of "total hairiness" of cotton yarn and the determination of mechanical factors contributing toward its formation (project duration - 5 yrs.); The Cotton Silk and Man-Made Fibres Research Association, Shirley Institute, Didsbury, Manchester, England, for a study of the effect of swelling agents on the fine structure of cotton (project duration - 5 yrs.), and for an investigation of chemical modifications of cotton fabrics involving control of lateral molecular order and distribution of crosslinks (project duration - 3 yrs.); Shri Ram Institute for Industrial Research, Delhi, India, for a fundamental investigation of moisture sorption and desorption by variously crosslinked cotton celluloses over the entire humidity range (project duration - 5 yrs.); State University of Ghent, Ghent, Belgium, for a fundamental study of the nature and origin of reversals in cotton fibers and their relation to mechanical properties of the fibers (project duration - 4 yrs.); and Swiss Federal Institute of Technology, Zurich, Switzerland, for a study of the chemistry and structural nature of

the bonds formed between formaldehyde and cellulose in formaldehyde-treated cottons (project duration - 5 yrs.).

Exploratory chemical and physical investigations are in progress under grants of P. L. 480 funds to the following foreign institutions: Birkbeck College of University of London, London, England, for a fundamental study of the preparation and properties of phosphazene and phosphoryl chloride derivatives having potential for reaction with cotton cellulose (project duration - 4 yrs.); The Hebrew University of Jerusalem, Jerusalem, Israel, for the synthesis and determination of properties of new aziridinyll phosphorus compounds having potential for use in the treatment of cotton (project duration - 3 yrs.); Indian Central Cotton Committee, Bombay, India, for an investigation of the preparation of radioresistant and radiosensitive celluloses (project duration - 5 yrs.); Ministry of Commerce and Industry of State of Israel, Jerusalem, Israel, for a fundamental study of the oxidation of cotton and crosslinked cotton by various oxidizing agents (project duration - 3 yrs.); Chalmers University of Technology, Gothenburg, Sweden, for a basic investigation of the behavior of cotton subjected to aerodynamic forces (project duration - 3 yrs.); and Shri Ram Institute for Industrial Research, Delhi, for a fundamental investigation of heat and mass transfer rates in the drying and curing of resin-treated cotton textiles by counter-current solid-gas contact systems (project duration - 5 yrs.).

The Federal in-house scientific effort devoted to research in this area totals 60.1 professional man-years. Of this number 35.7 is devoted to chemical and physical properties and structure and 24.4 to exploratory chemical and physical investigations. The domestic contract and grant research involves an additional 14.9 man-years, 10.0 being on chemical and physical properties and structure, and 4.9 on exploratory chemical and physical investigations. P. L. 480 research involves 21 grants, of which 15 are on chemical and physical properties and structure and 6 on exploratory chemical and physical investigations.

The following lines of work were terminated during the year: (1) Development of improved instrumental techniques for selected elemental analysis of additively and chemically modified cottons to aid in improvement of cotton textile products; (2) Fundamental investigation of crimp in cotton fibers and its relationship to other fiber properties, as well as its effect on processing performance and product quality (P. L. 480 project), (under Chemical and Physical Properties and Structure); (3) Exploratory investigation of the reaction of acetylene and related compounds with cotton cellulose (under Exploratory Chemical and Physical Investigations).

PROGRAM OF STATE EXPERIMENT STATIONS

Station research on cotton and cotton fiber utilization is directed to a number of application studies evaluating mechanical harvesting, ginning processes, and textile properties.

The influence of mechanical harvesting factors is being studied by several stations in the cotton belt. Two of these investigations relate to fiber quality and moisture content of seed cotton at the time of harvest. The extent of mechanically harvested foreign matter inclusions and composition of foreign matter have been subjects of interest for both the machine design and the gin operation. High speed motion pictures of harvesting action have served as a research aid in studying spindle action and elimination of foreign matter pick-up. It has been demonstrated that moisture vapor transport from trash to very dry field cotton results in a desirable water-tempering effect leading to improved ginning material which retains good staple length and, hence, fibers with better spinning potential. Evaluation of chemical agents as preharvest defoliants, controlants of weeds, cotton preservatives, and for fungicidal-moistening action on harvester spindles continues. In a study directed toward the development of new principles and techniques for ginning cotton, the use of electrostatic fields to remove and recover fly lint from gin exhausts is under investigation.

A program of research to develop improved instruments for measuring fiber characteristics such as length, fineness, maturity, tenacity, elongation, crimp, and compressibility is continuing. It is directed to provide convenient devices of precision for plant breeders measuring physical properties of small samples.

Knowledge of cotton plant growth is being developed to understand the transport of oxygen from air-permeated soils to germinated seedlings and the route of water vapor transport during emergence. Other studies include the catalytic behavior of trace metals such as molybdenum and manganese in cotton plant metabolism. The function of auxin in ethylene biosynthesis is inhibited by the presence in cotton of yet unknown water-soluble compounds containing phenolic groups. The toxic role of manganese as a co-factor in this reaction has been demonstrated in continuing studies of indoleacetic acid-oxidases. Disease resistance and susceptibility of cotton to xanthomonads has been associated with molybdenum nutrition of the plants and a study of amino acid patterns is being pursued to provide laboratory indicators of resistant and susceptible strains.

Three regional studies are directed to determining: (1) the mechanism of fabric stress absorption and performance; (2) the relation of fiber properties to end-product performance (cotton sheets); (3) properties of drapery and upholstery textiles and their importance to consumer satisfaction.

Other workers are conducting similar use tests of cotton garments and evaluating physical and chemical properties of fibers and fabric finishes.

A total of 13.7 professional man-years is devoted to this research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical and Physical Properties and Structure

1. Fundamental Investigations of Adsorption and Swelling Phenomena in Native and Modified Cottons. Microscopical investigations of absorption phenomena in native, mercerized, and modified cottons have continued. Preliminary experiments have been conducted on the use of lead acetate for electron staining of raw, scoured, slack and tensioned-mercerized fibers, and fibers from fabrics treated to different levels of crosslinking with formaldehyde. It has been demonstrated that lead, in the form of particles, is deposited in spaces within the fibers, but no definite correlation between particle size and radial structure has yet been made. Further studies of absorption by revised electron staining techniques will be carried out and the data correlated with that obtained via adsorption of nitrogen at liquid nitrogen temperatures in order to delineate differences in fiber microstructure of selected types of modified cottons. If feasible, similar observations of cottons swollen in various solvents will be made by the same techniques. (S2 1-209, S2 1-209(Rev.)).

In research to determine the properties and structural characteristics of cotton fibers which influence the capacity of the fibers to sorb alkaline solution, effort is being directed toward establishment of optimum conditions for the alkali swelling centrifuge test. Preliminary experiments have indicated that changing details of the test, such as duration of mechanical shaking and percentage of wetting agent employed, influences alkali centrifuge values (ACV) both in level and in variability. It was found that a 3.5-unit decrease in ACV resulted for each unit increase in moisture content of the conditioned specimens; this is due to the mathematical relationship rather than to a change in sorptive capacity of the cotton fibers. Specimens unduly exposed to lower atmospheric moisture conditions after removal from the centrifuge had lowered ACV's, presumably due to loss of moisture to the atmosphere. The effect of centrifugation time apparently varies with the morphology of the fibers. Also, ACV is influenced by the percentage of sodium hydroxide in the soaking solution. These test variables will be investigated further. Additional ACV data on intracard specimens confirmed again the usefulness of the ACV test in investigating the possibly deteriorative actions of components of processing machinery, as indicated by increased ACV's. (S2 1-249).

Basic studies of the relationship of molecular parameters of organic compounds to their swelling power on cotton cellulose have been initiated in contract research at the Polytechnic Institute of Brooklyn. It has been shown that use of the differential dyeing technique may not give a valid measure of the swelling of cotton. A differential scanning calorimeter has been installed and calibrated; it will be used for detecting heat changes during the swelling of cotton in selected nonaqueous media. Some progress has been made on the use of microscopical techniques to measure cross-sectional areas of swollen cottons and to follow changes in fiber dimensions

with swelling in nonaqueous media. Correlation of heat changes with changes in fiber dimensions should aid in the elucidation of the phenomena involved in the swelling of cotton. (S2 1-225(C)).

2. Basic Studies of the Relationships of the Structural Arrangements Within Cotton Fibers to the Physical Properties of Native and Modified Cottons.

Microscopical techniques have been applied to various types of chemically modified cottons to observe differences in fiber structure. In investigations of crosslinking mechanisms, microscopical comparison of products of divinyl sulfone and of bis(hydroxyethyl)sulfone treatments indicated that both of these treatments had produced fibers well enough crosslinked that no layer separation could be induced by the layer-expansion specimen preparation technique. Preliminary exploratory investigations of the reforming of broken crosslinks in samples treated with the reactive dye "Remazol G" (sulfone crosslinking agent), and subsequently reduced by zinc hydrosulfite, indicated that diazotization followed by treatment with coupling agents could be followed microscopically by the layer-expansion technique and by swelling of the cross sections in cupriethylenediamine. In the experiments tried, neither H-acid, nor chromotropic acid reformed the crosslinks, but resorcinol did. Dialdehyde cotton showed distinct layers, comparable to those found for untreated cotton, when sections were embedded wet in methacrylate; however, crosslinking dialdehyde cotton with carbohydrazide gave a product in which the majority of fibers showed no layer separation by the layer-expansion technique. Observations of cotton fibers grafted with polymethyl methacrylate and polyacrylonitrile by postirradiation methods indicated that the fibers are more heavily reacted in the outer regions; whereas, with polyvinyl acetate, reaction occurred more uniformly throughout the whole fiber. Changes in refractive index of cotton fibers mercerized after crosslinking with butadiene diepoxide indicate that post-mercerization does affect birefringence in samples pretreated with 2% sodium hydroxide but not those pretreated in 15% or 23% sodium hydroxide. The former samples showed no change in orientation on aging, but those pretreated with the higher alkali concentrations did exhibit changed refractive indices on aging. Measurement of refractive index may become a useful tool for additional evaluation of chemically modified cottons. Location of areas of graft polymer within the cotton fiber will assist in the interpretation of mechanisms in high energy radiation experiments. (S2 1-263).

In research on the effects of gross and fine structure of cotton fibers on their physical behaviors, the relationships of tenacity to cellulose orientation found in earlier investigations have been substantiated in experiments with another series of American and Asiatic type cottons having a wider range in properties. Toughness ($1/2$ tenacity \times elongation) and crystallite orientation are not linear relationships irrespective of cotton variety; the Pima S-1 type cottons have higher tenacity for comparable orientation than the American upland type. High crystallite orientation in general is related to high cellulose density, a relationship which is more pronounced if water solubles are removed. Experiments where high tension was used during resin treatment of several varieties of cotton in the form of 16/2

low-twist yarn confirm the large effects of tension. High tension may increase the strength of slack mercerized yarn over that of the tension mercerized control, but even low tension is sufficient to restore the strength of slack mercerized, acid degraded yarns to the strength of their controls. Although slack resin treatment does not appreciably change the modulus or stress-strain curve of the slack mercerized, acid degraded yarns, high tension during the resin treatment of these yarns may increase modulus over 24-fold. Tension during resin treatment does not generally affect the toughness. Fibers with structural differences caused by growth conditions and by species will be examined for relationships.

Special cottons grown in growth chambers (see project S2 1-217(C), below) under conditions of constant illumination but varying temperature have been found to develop diurnal growth rings, although no diurnal growth rings developed when temperature was kept constant and light varied. Many properties of the fibers grown in chambers with varying light and temperature as encountered under outside conditions were generally comparable to those of field-grown cotton. Cell walls of fibers grown under constant conditions of temperature, moisture, and illumination, observed with the optical microscope after swelling with cuprammonium hydroxide, disclosed no evidence of a striated structure as found in field-grown cotton. However, when methylmethacrylate, a strong swelling agent, was used to swell the cell walls, the fibers ruptured into similar layers or fragments regardless of growth conditions. Only small differences in strength, elongation, and cellulose orientation were found for cottons with and without growth rings. This further substantiates the observations of comparable basic structure and indicates that the growth ring structure could be relatively unimportant. The spirality of structure and reversals are found in cotton grown under constant conditions. (S2 1-208).

Cottons are being grown in growth chambers under various controlled conditions of temperature, illumination, humidity, etc., by the contractor (Texas Agricultural Experiment Station) for studies of fiber structure differences caused by environmental and genetic factors. Conditions of growth have been found to affect plant development, fiber properties, and the period required to develop the fiber. Environmental effects on the five varieties of cotton investigated were found to vary, the Rex variety being the most consistent producer of developed fibers under the various light-temperature conditions studied. One strain, NR-AHA-C, has shown unsatisfactory response to flower setting and fiber production under the conditions investigated. The diurnal growth ring structure was found in cottons from a temperature fluctuating environment rather than a light fluctuating environment. Various properties of the specially grown cottons are being studied in detail in the aforementioned project, and in the Plant Fibers Pioneering Research Laboratory. (S2 1-217(C)).

Fundamental information concerning fiber components that contribute most to the strength properties of cotton is being developed in contract research at Stanford Research Institute. Although the treatment of cotton yarn with

various types of swelling agents has been found to cause changes in the internal fiber structure, only the swelling agents that are capable of breaking strong hydrogen bonds between the cellulose chains are capable of improving the strength properties. Electron micrographs of the surface and cross section of fibers treated by various types of swelling agents do not indicate structural changes that are associated with strength properties. The conversion of crystalline cellulose I to cellulose II apparently is not necessary to obtain increased molecular orientation by swelling-tensioning treatments. Most of the conversion apparently takes place during washing when sodium hydroxide solutions are used. Swelling of chemically modified cotton that swells only in the regions of modification does not result in improved strength properties on subsequent mechanical stretching. (S2 1-206(C)).

Fundamental studies of the role played by the structural elements of the cotton fiber in response to stress are being conducted in P. L. 480 research at the Central Laboratory, T.N.O. under a project now nearing termination. Through the use of modern microtechniques for manipulating and observing single fibers, a better understanding is being obtained of the internal movements that occur within the cotton fiber while it is being subjected to torsion and stretching. Fibers treated by resin treatments commonly used in wash-wear finishing of cotton have been found to be more rigid to torsion and to begin to form cracks and break at lower torsion than untreated fibers.

Observations of stress concentrations and slip phenomena in native and resin treated fibers are furnishing new data that confirms present views and extend the knowledge of cotton fiber structure and behavior. Such basic knowledge of cotton fibers eventually will be directed toward efforts to improve cotton fiber properties through cotton breeding programs and improvements in cotton processing. (UR-E19-(20)-4).

Research under a P. L. 480 project at the fiber Research Institute, T.N.O., in Holland to investigate the fundamental mechanisms and bonding forces that could be used to improve the tensile strength and other physical properties of cotton textiles is now in its early stages. An excellent survey of current literature in this area of research has been made. Work is now underway to determine the physical and mechanical properties of combed yarns after treatment with various media that strongly swell cotton fibers. Information growing out of research under this project is expected to be useful in improving processing treatments to yield cotton fabrics having improved strength characteristics. (UR-E19-(20)-12).

In P. L. 480 research at the Swedish Institute for Textile Research, reactions which will cause setting in cotton fabrics and garments are being investigated. Treatment of cotton fabrics with solutions of certain inexpensive alkalis or inorganic salts which cause swelling of the cotton fibers has been shown to cause the relaxation of internal stresses in the fabrics. This treatment, which is generally known as "setting," decreases surface mussiness of the fabric, and in combination with standard resin

treatments, results in improved wash-wear properties. It has been observed that the conditions under which deswelling of the fibers occur during treatment greatly influence the "setting" effect. More recently, a study has been made of the "setting" effect, when used alone, of inorganic salts that are used as catalysts in resin treatment of fabrics. Setting determinations have also been conducted under condition of time, temperature and concentration similar to those employed in industrial finishing, such as mercerizing, kier boiling and bleaching, to obtain a better understanding of these processes from the point of view of "settings". Information developed is expected to assist in providing the basis for reducing the amount of resin required to provide acceptable wash-wear qualities in cotton textiles. (UR-E26-(20)-2).

3. Elucidation of Mechanisms of Physical Damage to Cotton Due to Mechanical, Chemical, Physical or Biological Actions. Investigations to determine the effects of fiber extensibility on fiber breakage in mechanical processing have been initiated under contract at the University of Tennessee. Initial techniques developed and investigated for possible application in determining differences in fibers related to fiber extensibility or ease of breakage in processing involved the crushing of fibers with known forces, and determination of torsional properties of the fibers before and after crushing. The research has shown that the magnitude of differences in fiber geometry is sufficiently large that changes in structure estimated from changes in torsional rigidity should be determined on the individual fibers before and after the structure change rather than on fibers randomly selected from the bulk samples. Since the torsional property changes resulting from crushing single fibers are dependent upon both the changes in fiber geometry and the fiber damage, use of the individual-fiber test approach for determining torsional changes on the crushed fibers is not informative. The most reproducible method found thus far for determining resistance to crushing as indicative of brittleness is the application of pressure to a plug of cotton fibers. Techniques for measuring density, torsional rigidity, and moisture regains as indicative of changes in fiber structure have been standardized and the statistical reliability established. (S2 1-221(C)).

An investigation of the photochemical breakdown of cotton under different conditions of exposure to radiation is being continued in P. L. 480 research in India at the University of Bombay. It is well known that cotton fabrics are weakened by prolonged exposure to sunlight or to strong illumination. Progress is being made toward determining the mechanisms by which photosensitization and photolytic degradation of cotton and selected modified cottons take place. Photodegradation has been shown to proceed by random chain scission, the course of which is represented by two stages, each obeying first order kinetics, the initial stage proceeding at a faster rate of reaction than during the subsequent stage. The role of moisture in photochemical degradation of cotton and modified cottons has been clarified. Basic knowledge of this type is expected to be useful in devising practical means to prevent the deterioration of exposed cotton fabrics by means

of chemical inhibitors or screening agents that prevent or interfere with the sequence of reactions involved. (UR-A7-(20)-4).

Under a P. L. 480 grant at the University of Bombay, a study is being made of new, more stable solvent systems for cellulose in the determination of the average molecular weight of cellulose by the disperse viscosity technique. Copper complex solvent systems widely used for this purpose are highly colored and are extremely oxygen-sensitive, factors which greatly complicates their preparation, storage, and use. Substantial progress is being made in studies of several iron tartrate and cadmium ethylenediamine complex solvents that are relatively colorless and insensitive to atmospheric oxygen, and in relating data obtained with them to comparable data with the older copper complex systems. Means have been developed to apply a two-component solvent system to the dissolution of high degree of polymerization cottons and mercerized samples that are difficult to dissolve in the usual solvents, thus permitting satisfactory measurement of these materials. Studies have been made of the kinetics of degradation of cellulose solutions at several temperatures and attempts have been made at fractionation in iron tartrate solvents. The information obtained in this project will be useful in following the degradation of cotton by various treatments, through the application of a simplex procedure for intrinsic viscosity measurement. (UR-A7-(20)-30).

4. Investigation of the Structural and Compositional Changes Occurring During Chemical and Physical Modification of Cotton Cellulose. Pioneering research on plant fibers has been pursued along a number of lines by the Plant Fibers Pioneering Research Laboratory. Considerable attention has been given to the crystalline state of various cellulosic materials, chiefly through the use of X-ray diffraction procedures. Three aspects of the crystalline nature of cellulose are under examination. These include (1) the degree of crystallinity, (2) the size of the crystalline regions, and (3) the change in crystal geometry as a result of chemical modification. A new readout system for the X-ray diffractometer has been installed, which will provide punched tape and/or typewritten data as well as potentiometer recorder tracings of diffraction curves.

A method for obtaining the degree of crystallinity of cellulose by point-by-point comparison of diffraction intensities of highly crystalline, highly amorphous, and the experimental material was developed of some years ago under research contract for SU by Wakelin and his associates at Textile Research Institute, Princeton, New Jersey. The method overcomes many of the theoretical objections to X-ray crystallinity measurements, but is rather tedious in the mathematical treatment of the data. To take advantage of the validity of the method, a computer program has been written which employs punched tape data. The computer operations have been carried out on the IBM 1620 computer at the ARS computer center at Beltsville, Maryland. Cottons of the same variety grown in the field and under controlled environmental conditions of light and temperature at the Texas A&M Experiment

Station were examined by the programmed Wakelin technique. Significantly higher crystallinity was found in the field-grown cotton fibers, whereas estimations by the empirical peak intensity measurements had shown relatively little difference.

In the studies of crystallite size by X-ray diffraction procedures, means of avoiding the excessive computations required are under development through use of the punched tape readout system of the diffractometer and computer processing at the computer center at Beltsville, Maryland. The crystallite dimensions of several celluloses have been estimated from measurements of the peak width of the tracings of the (002), (10 $\bar{1}$), and (101) interferences. (In each case, these interferences arise from interplanar spacings perpendicular to the chain direction of the cellulose, and therefore represent diameter measurements of the crystallite.) In a given sample, each interference gave approximately the same value for the crystallite diameter. Untreated cotton crystallites had a diameter of approximately 50 Å; this increased to 60 Å in cotton cellulose after hydrolysis. Commercial wood hydrocellulose (Avirin) had a diameter of approximately 33 Å. Fourier analysis has not yet been applied to these experiments, but it is hoped that some estimate may be obtained also of the distribution of crystallite sizes which make up the average.

Introduction of ester or ether groups into the cellulose molecule disrupts the interplanar spacings originally present, and brings about new crystalline arrangement of the modified cellulose chains. In a series of derivatives in which the group introduced was relatively large, new interferences were found which arose at the expense of the original (101) spacing, and which correspond to much larger interplanar distances. In an extreme case, the menthyl terephthalate ester of cellulose displayed a (101) interplanar spacing of approximately 25 Å - a 240% increase. This is the largest spacing thus far found in chemically modified cotton which still retained useful fiber properties. In general, the lattice distention accompanying chemical modification was found to be proportional to the size of the group introduced, although the position taken up by the group strongly affects the extent of the change. Thus, both benzhydryl (diphenylmethyl) and trityl (triphenylmethyl) cellulose have a smaller interplanar spacing than benzyl (monophenylmethyl) cellulose. This can only arise if the benzene rings of the trityl and benzhydryl groups take up an average position which is relatively flat, i.e., perpendicular to the plane of the anhydroglucose ring of the cellulose chain. In continuing work it is planned to determine the dimensions of the unit cells and the crystallite sizes of the modified celluloses currently under study.

Studies to reveal the extent of development of crystalline cellulose at different stages of growth are being continued. The effects of the environmental factors of light and temperature during fiber growth on the fine structure of the cellulose in the fiber are being examined. Under contract S2 1-217(C) cotton bolls are being grown at Texas A&M University in growth chambers under controlled conditions. The first series of bolls,

grown under continuous illumination and an alternating temperature schedule of 15 hr. at 80°F. and 9 hr. at 70°F., have been received and some preliminary examination has been made. A second series, grown under continuous light and alternating temperatures of the same intervals at 90°-70°F., have been harvested.

Some tests are under way to compare freeze-drying as opposed to storage in absolute methanol as methods of preservation of fresh or undried fibers. Also, storage in water and solvent-exchange to pentane, with removal of pentane under nonaqueous conditions is being tried.

Studies of the structural organization of cellulose as revealed by kinetics have continued. One phase of this work involving heterogeneous cyanoethylation was completed. The reaction was carried out on fibers saturated with 6% aqueous sodium hydroxide catalyst, by reacting them with liquid acrylonitrile at a preselected temperature for the desired time. The application of Sakurada's equation for a diffusion-controlled chemical reaction and fundamental kinetic laws were considered. The effects of temperature from 31°C. to 60°C., dilution of the reagent with different organic liquids, reduction of crystallinity prior to reaction, and previous distribution of catalyst in the fiber were considered with respect to their effect on the reaction rate. Sakurada's equation was found to be obeyed approximately at the higher reaction temperatures but deviations were observed at the initial stages. The rate of reaction generally falls abruptly toward the later stages. The position of the sudden change of rate is somewhat dependent on the temperature and was found to be associated with the change of cellulose crystal structure. Approximate energies of activation, calculated from the specific rate constants between 31° and 40°C. and between 45° and 50°C., were 10.6 and 16.7 kcal., respectively. An empirical relation was found between the constants of Sakurada's equation and correlated with the Arrhenius equation. Energies of activation determined from this relationship were very close to those found in limited ranges by the conventional methods. The mechanism of the reaction is interpreted as a diffusion-controlled process in which hydrogen bond rupture plays a significant role in diffusion.

In connection with a kinetic study of the cyanoethylation of scoured cotton cellulose, it was observed that during the later stages of reaction the product becomes yellow to orange colored and contains considerably more nitrogen than can be accounted for by the simple addition of cyanoethyl groups at each hydroxyl of the anhydroglucose residue. An infrared study has been made of the products at progressive stages of reaction and of certain soluble products and byproducts of the reaction. The infrared absorption spectra of the samples and of the reacted residues show various types of absorption bands characteristic of amino groups. There is also an indication, inferred from a weak band accompanying the nitrile stretching band, of the formation of small quantities of ionic cyanide as a byproduct. At advanced stages of the reaction the broad band in the 1200-950 cm^{-1} region, characteristic of the cellulosic fiber, largely disappears leaving only a few weaker bands due to C-N stretching. Comparison was made of the

spectra of the partially cyanoethylated cellulose and the polyacrylonitrile which forms in the stock acrylonitrile, in an effort to characterize the products. It is concluded that the highly cyanoethylated cellulose, partly dissolved in the acrylonitrile, degrades progressively in the presence of alkali and changes through a complex mechanism to various amine derivatives. The yellow to orange color of the highly reacted samples is assumed to be due to these byproducts.

The study of the kinetics of a heterogeneous cellulose propionation reaction has also been completed. Cotton fiber was reacted with propionyl chloride in pyridine. The kinetics of reaction did not obey Sakurada's equation closely and the deviations were more noticeable at lower initial concentrations of the reagent and at lower temperatures. The rate of substitution changed twice during the reaction, the second change being associated with the loss of the cellulose I structure. However, at the final stage of the reaction, when the cellulose I structure was completely lost, the reaction behaved as a first order type. The diffusion equation has been applied in the present reaction by considering that the amount of diffusion of the reagent into the region, which was initially crystalline, would be proportional to the decrease of the cellulose I crystallinity. The mechanism of the reaction in the crystalline and the amorphous regions was examined. It has been concluded that in the crystalline region the hydrogen bond-breaking process has a significant role in governing the reaction.

The effects of chemical modification on the structure and mechanical behavior of plant fibers have also been investigated. Considerable work has been carried out using the pyridine-acyl chloride procedure for the preparation of test-scale quantities of yarns representing different degrees of substitution with ester groups. The Teflon-glass reactor, described in previous reports, was used in the preparation of a series of cellulose 2-ethylhexanoates and of a series of cellulose 3,5,5-trimethylhexanoates. Pyrolytic studies on these esters have shown that at elevated temperatures the ester linkages cleave to yield the free acids. These acids can be separated from cellulose degradation products by gas chromatography. The quantity of acid produced is proportional to the D.S. and can be used to determine the extent of reaction. This finding is important since the esters are strongly resistant to saponification, the procedure ordinarily used to determine the degree of substitution of esters.

The relationship between the configuration of an acid chloride and its ability to react with cellulose has been investigated further using the d, l, and dl forms of monomethyl terephthaloyl chloride. With these acid chlorides it was found that the reactivities toward cellulose in pyridine fall in the following order: dl > d >> l. The fact that the dl modification is somewhat more reactive than the d form was unexpected and is as yet unexplained.

The stereochemical investigations have been extended to include reactions between cellulose and camphoric acid derivatives. While stable cellulose

esters have been prepared from these derivatives, contradictory data in the literature on the camphoric acid intermediates have complicated the interpretation of the stereochemistry involved. These studies are being continued.

During this period most of the data have been recorded and computed for the effects of benzhydrylation on cotton yarn properties. Substitutions include D.S. (degree of substitution) equal to 0.31, 0.46, 0.87, 1.13 and 1.22. Tensile strength and elongation at break have been determined under standard atmospheric conditions. Tensile strength decreases very slightly (up to 16%) as substitution increases while elongation increases about 75%. The result is that toughness also increases substantially (ca.55%). Due to substantial increases in yarn number (up to 115%) the strength of the yarn, computed as tenacity, decreases about 60%. The density of the fiber substance decreases progressively with substitution from 1.531 g/cc in the control to 1.362 g/cc at D.S. = 1.22, a maximum of 11%. The X-ray diffractograms show that the starting cellulose is incompletely mercerized and that the crystallinity decreases progressively with substitution. The introduction of a small amount of benzhydryl groups (D.S. = 0.31) takes place largely in the residual native crystalline component, leaving a sharp hydrate crystalline pattern. The crystallinity never disappears completely but the beginning of crystalline structure, due to the presence of the benzhydryl group, shows at D.S. = 1.12. Stiffness modulus, and elastic and work recovery have been measured on each substituted yarn and on controls at temperatures from ambient to 225°C. and back again, carried through two complete cycles. In most cases each of the three measures differs strongly during the first heating cycle from the corresponding values during the second heating cycle and both cooling cycles. Evidently, a very fundamental structural change takes place during this first heating cycle. Evidence of second-order transitions are present. The results, thus far, are tentative and analysis and interpretations are proceeding.

A rather detailed study was made of the thermal behavior of samples benzhydrylated to various degrees of substitution from 0.31 to 1.22. Both differential thermal analysis (DTA) and thermogravimetric analysis (TGA) were applied to these samples in helium and air atmospheres. Controls consisted of the original untreated cellulosic yarn and the same subjected to the same media and temperatures in the absence of the reactant (benzhydryl bromide).

In an atmosphere of helium the control cottons showed a small DTA endotherm associated with moisture loss and two well-developed exotherms. The lower begins at about 350°C. after the cellulose has largely volatilized and continues to about 425°C. The second exotherm begins at about 450°C. and disappears suddenly at about 530°C. It is apparently associated with the final stage of the breakdown of the cellulose. Thus, the DTA curves suggest two separate pyrolytic reactions. All of the substituted celluloses in helium show very nearly the same type DTA curves as the controls with two exceptions. No endotherm, due to moisture loss, is seen. And a small endotherm, presumably associated with scission of diphenyl methane, is

superimposed on the initial exotherm at 350-425°C. so that a dip appears there. This endotherm shows little or no change of magnitude related to degree of substitution. The results suggest three successive or overlapping reactions, one requiring energy to initiate, the other two supplying energy.

Interestingly, the pyrolysis of samples in air follows nearly the same pattern as in helium, the principal differences being that the reactions begin at 20-30°C. lower temperature. Again the controls show small endotherms associated with moisture loss and two well-developed exotherms. The lower exotherm again begins after most of the cellulose has volatilized. The introduction of benzhydryl groups into the cellulose leads to the appearance of an endotherm which is superimposed on the initial exotherm of the control samples. Another characteristic feature of the DTA thermograms in air is the much greater magnitude of the exotherm at 450-550°C.; this increases progressively with substitution. There is no evidence that the substituents diphenylmethane, or to a lesser degree, benzophenone, separate from the cellulose at a different temperature from that of the cellulose breakup. Therefore, it must be assumed that they are first liberated as a result of cellulose breakup and do not anticipate the latter or even accelerate it.

A study on the rate of decomposition of cellulose under isothermal conditions has been initiated. Experiments were carried out under helium atmosphere at different temperatures with ball-milled and cut cotton cellulose. The kinetics were followed by determining the weight loss of the material with time at a given temperature. It has been found that after a decomposition of the first 40-50% of the cellulose the reaction behaves as a first order type. The energy of activation was calculated to be 33-37 kcals. The initial reaction on the other hand was found to follow a completely different mechanism which could be treated as a chain reaction. The energy of activation for the initiation of the chain reaction has also been calculated. With cotton cellulose it was about 54 kcals., but with ball-milled cellulose it is much higher than that of the cotton. Infrared spectra of several heat-degraded samples were taken and the absorption bands which developed or were changed have been investigated. The crystallinity index of the samples was determined by infrared technique. X-ray diffractograms of those samples were also obtained. These results are being analyzed in order to get a detailed picture of the mechanism of cellulose pyrolysis. Various proposed reaction mechanisms have been considered and a kinetic equation has been formulated.

A new technique for the application of thermogravimetric analysis to kinetics of pyrolytic reaction has been developed and applied. Theoretically, this is applicable for determining the Arrhenius parameters of reaction order, energy of activation, and frequency factor for each individual reaction in a series of consecutive and simultaneous thermal reactions. Two thermograms are required with different weights of the sample under otherwise similar reaction conditions. The new method is easier mathematically compared to the earlier methods and should supply more information concerning the mechanism of reaction.

Research on crystal lattice changes in fully acetylated cotton has been completed. It was shown by means of gas chromatography, infrared spectra and saponification observations that acetyl groups in acetylated cotton (DS = 2.93) are not replaced by immersion in 72-98% formic acid at 26°C.

Physical chemical studies have been planned which, it is hoped, will help to clarify the nature of the microfibrillar organization of cellulose. Considerable evidence in the recent literature indicates that the matter of the fine structure of cellulosic fibers is far from settled. Based mainly on electron microscope data, these latest postulates envisage folding of the cellulose chain molecule, absence of amorphous structure, elementary microfibril structure instead of fringe-micelle, and the like. Instruments required for the proposed research have been acquired. Included are a Reichert Zetopan research microscope, specially designed precision viscometers, and a Perkin-Elmer Sorptometer. (SU P2).

In other in-house research (not in PF Pioneering Research Laboratory), improved infrared spectral techniques for the study of modified cottons have been developed. Differential infrared spectra of crystalline and decrystalline hydrocellulose I and II have been obtained for the purpose of differentiating the polymorphic forms. Although no new bands have been developed by this technique, there is an advantage in the sharpening of the absorption bands present. The technique of "frustrated multiple internal reflectance" (FMIR) has been successfully applied to obtain infrared spectra of many types of treated cottons. Certain changes in absorption noted in FMIR spectra of the treated samples seem to be surface effects and may possibly result from variations in crystallinity; these differences have not been perceptible by other infrared techniques. Interpretation of these differences may be of use in evaluating molecular structural changes produced by the chemical treatment of cotton cellulose. An additional advantage of the FMIR technique is that spectra can be obtained without changing the physical state of the fabric. In another phase of work, spectra obtained by the KBr disc method on reaction products of several model compounds, including carbohydrates related to cellulose, with DMEU and with formaldehyde, are being interpreted. (S2 1-220).

Development of improved instrumental techniques for elemental analysis of additively and chemically modified cottons has continued. Satisfactory techniques have been devised for quantitative determination of an additional element, silver, in cotton textile materials by the X-ray fluorescence method. Twenty two elements have now been satisfactorily determined by this method. Atomic absorption spectroscopy has proven suitable for determination of potassium at the part per million level. Recent improvements in the method for X-ray fluorescence analysis of cotton textile materials has made it possible to obtain more precise and reliable results. Also, techniques have been developed for accurately determining elements in liquid samples down to 0.05% concentration in some instances. Because of masking by the liquid, this level of analysis is not as low as for solid samples. Correlation of the X-ray fluorescence data with those by atomic absorption will be made. (S2 1-218).

Research has been initiated to investigate the fluorescence spectra of native and modified cotton. A commercial-type spectrophosphorimeter has proven inadequate for the spectrofluorometric examination of solid samples due to the excessive stray light in the monochrometers. An atomic spectrofluorimeter is being procured for use in the research. Extracts of chemically treated cotton batting and modified cellobiose (used as a model compound) have been found to exhibit absorption in the ultraviolet region, which indicates that these samples may exhibit fluorescence when observed with proper instruments. (S2 1-264).

Procedures have been developed for obtaining nuclear magnetic resonance (NMR) spectra of acid hydrolyzates of various treated cotton fabrics and of reaction products of certain crosslinking reagents with model compounds related to cellulose. These spectra may furnish information regarding the location of the hydroxyl functions in these products. The development of new basic information concerning the reactions of cellulose by use of NMR spectroscopy should aid research on the chemical modification of cotton. (S2 1-268).

Research has been initiated to develop new X-ray diffraction techniques for the study of crystalline cotton cellulose and chemically modified cottons in contact with various swelling liquids; and to apply the techniques in a study of the basic factors responsible for swelling. Suitable sample holders have been designed and tested. Preliminary experiments have made it apparent that, in those cases where complex formation does not occur, excess liquid, due to its partial absorption and diffuse scattering of X-rays, will pose a considerable problem in the evaluation of any decrystallization effects on the cotton. Careful adjustment of the sample-to-liquid ratio will be necessary. Also, the relative humidity at which cotton samples are conditioned was found to influence their X-ray diffraction patterns to some extent. (S2 1-276).

Progress is being made in separating and identifying the cleavage products of partially etherified cottons to elucidate the structure of the modified cottons. The identification of 6-O-methylsulfonyl ethyl glucose as the major substituted glucose formed in the reaction of methyl vinyl sulfone with cotton cellulose has established that the reaction occurs predominantly, if not completely, at the hydroxyl group in the 6-position of the anhydroglucose unit of cellulose. Methyl vinyl sulfone-modified cotton fabrics prepared under a variety of conditions of reaction will be investigated in order to determine the effect of method of preparation on reaction site. The study will then be extended to other chemical agents including crosslinking reagents such as divinyl sulfone. (S2 1-214).

Research to investigate distribution, type, and effectiveness of crosslinks in cotton cellulose by dissolution and swelling techniques is in progress. A reliable and reproducible method has been developed for determination of cupriethylenediamine hydroxide-soluble cellulose in the presence of nonsoluble components. The method has been applied to a series of cottons

treated with a wide variety of di- and polyfunctional agents with interesting results. It is now possible to measure quantitatively the degree to which cotton cellulose is insolubilized by chemical agents in crosslinking treatments. In the case of formaldehyde-modified cottons, it has been found that the level of formaldehyde required for complete insolubility of cotton cellulose in cupriethylenediamine hydroxide varies by more than an order of magnitude from one to another process of reaction. The Form D process conducted in acetic acid stands out in its high requirement of formaldehyde for complete insolubility. The autocatalyzed esterification of cotton with formic acid has been investigated and found to be an effective means for characterizing reactivity or availability for reaction of hydroxyl groups in cotton celluloses modified by various physical and chemical means. Also, an insight into the relative reactivities of the hydroxyl groups has been obtained from a kinetic treatment of the formic acid reaction of a low molecular weight soluble carbohydrate. The specific velocity constant for the primary (No. 6) hydroxyl is approximately double the sum of the velocity constants for the secondary (Nos. 2 and 3) hydroxyls. (S2 1-255).

A fundamental investigation of the effect of swelling and stretching treatments on the fine structure and mechanical properties of cotton fibers is being conducted under a P. L. 480 grant at the Amedabad Textile Industry's Research Association (ATIRA), in India. The effect on fiber fine structure, as revealed by X-ray, microscopic and modulus measurements, of swelling fibers under tension with agents such as solutions of sodium hydroxide, ethylene diamine, and zinc chloride is under study. An instrument technique for measuring the viscoelastic properties of modified cottons has been developed. It has been shown that orientation is considerably more decisive than crystallinity in determining the elastic modulus of cotton fibers. The information being obtained in the investigation is expected to be useful in the selection of treatments to improve the mechanical behavior of cotton products. (UR-A7-(20)-19).

In a P. L. 480 project now nearing its final phases, a basic study of the fine structure of the cotton fiber is being conducted at the National Institute of Applied Chemical Research in Paris, France, to relate fine structure to other fiber properties that are important in the processing and use of cotton. Refined physical and chemical techniques, including X-ray diffraction and microcalorimetry have been applied to the measurement of fine structural features and behaviors of a typical U. S. Cotton of Deltapine variety for which extensive fiber data were available, and to the same cotton treated at several levels of three well-known crosslinking treatments. Extensive data on parameters such as moisture sorption, swelling, crystallinity, and specific surface area have been collected and will be subjected to analysis and interpretation. The information obtained eventually will be translated into the development of improved cotton products. (UR-E9-(20)-61).

A P. L. 480 project is underway at the Shirley Institute, Manchester, England, in which a study will be made of the effect of caustic soda and other swelling agents on the fine structure of cotton. The first phase of the

project, in which a comprehensive and critical survey of of the literature on the swelling of cotton is being made, is now largely completed. This survey will fill an urgent need of researches in the field of swelling and its practical implications in processing and will be made available to them. A record phase of the project, now getting underway, is designed to fill gaps in the literature of swelling made apparent in the survey. (UR-E29-(20)-65).

5. Relationship of Gross Structure of Cotton to Behavior of the Fibers in Textile Structures. A fundamental investigation of the interfiber frictional force and associated fiber properties to improve the processing of cotton products has been successfully completed. Recent work has involved studies of the effects of draft direction and fiber hook removal on processing performance for an extra long staple cotton. In these experiments the cotton was processed into combed and carded yarns using various drafting directions. It was found that when a minimum of fiber hooks trailed into the comber, less noils were removed, better fiber separation occurred, and a more uniform comber sliver was obtained. There were fewer long fibers in the noils and fewer short fibers in the comber sliver. Fiber hooks were reduced to such an extent by the comber and post comber operations that their effect on end breakage and yarn properties was negligible. Generally, drafting with the majority hooks trailing at first and second drawing, leading at roving, and trailing at spinning increased spinning efficiency for carded yarns of the long staple cotton, as was previously found for the short and medium staple cottons. Drafting tenacities of slivers were found to be linearly related to the total amount of fiber hooks. The findings from this research should assist mills in improving their combing and spinning efficiency. (S2 1-201).

Basic research was recently initiated under a grant at Georgia Tech Research Institute to elucidate the role of fiber morphology on frictional behavior important in mechanical processing of cotton fibers and in the behaviors of cotton products. Initial phases of the work will involve a literature survey and the development of techniques for characterizing the surface and morphology of the cotton fiber. (S2 1-248 (Gr)).

Basic investigations of the configurational interactions between fibers and yarns in regions of local deformations in woven cotton textiles have been initiated under a grant at the Massachusetts Institute of Technology. Initial efforts have been concerned with a determination of the extent to which classical engineering concepts can be applied to the bending and unbending of cotton structures. Development of valid engineering concepts and mathematical models to describe the complex movements of cotton fibers in yarns in fabrics during bending and unbending will provide the basis for design and construction of improved textiles for specific uses. Of particular importance in the development of these concepts is the extent to which friction enters into the mechanical distortion of fiber assemblies. (S2 1-237 (Gr.)).

A fundamental investigation of fiber crimp, a property possibly responsible

for differences in mechanical processing behavior of cotton fibers, was recently completed under a P. L. 480 grant at the Ministry of Commerce and Industry of the State of Israel. An ingenious apparatus consisting of an optical projection system and a special curve tracer was developed which, used in conjunction with an electronic computer, permitted continuous and dynamic measurements to be made of fiber crimp diameter, considered to be the main crimp parameter of cotton fibers. Using this technique studies were made of crimp in a number of cottons of different physical characteristics on which extensive property data were available. Salient observations were that natural crimp in cotton fibers is a function of fiber size and length rather than a genetic characteristic and is independent of convolutions, reversals in cellulose structure, and crystal orientation angle; fiber crimp tends to be progressively removed in passing through the stages of processing; and cottons of greater crimp tend to behave as shorter, coarser fibers in the spinning process. (UR-A10-(20)-5).

Research is progressing under a P. L. 480 grant at the Juan de la Cierva School of Technical Investigations, Barcelona, Spain, to devise means for the measurement of "total hairiness" of cotton yarns and to determine mechanical factors that contribute to the formation of this phenomenon in the spinning of cotton. It is thought that higher spinning speeds cause increased "hairiness", a fuzzy condition resulting from the protrusion of fiber ends from the body of the yarn. Since for many uses yarns are singed to remove this hairiness, the amount of fibers so removed could have important economic implications. Substantial progress has been made in the development of a prototype apparatus to measure and record the "total hairiness" of cotton yarns employing electronic circuitry. Means to measure this phenomenon is expected to be useful in that it will permit machine adjustments to be made in processing cotton to minimize the formation of hairiness in yarns. (UR-E25-(20)-31).

6. Investigation of Factors Influencing Comfort in Cotton Textiles. The contractor (Harris Research Laboratories, Inc.) has initiated research investigations of factors influencing comfort in cotton apparel fabrics. Experiments conducted in an environmental test chamber have demonstrated the ability of subjects to distinguish differences in sensations of comfort in oxford and broadcloth cotton shirtings under both warm and cool stress conditions, and have permitted selection of physical properties of fabrics which appear to correlate most closely with subjective response. Since it has been found that resin treatment of fabrics for wash-wear finishing, as such, does not reduce the permeability of the fabrics to water vapor, surface properties and thickness-pressure, i. e., structure, relationships appear to be of importance in influencing comfort. A 15-fabric series of shirtings varying in weight, surface characteristics, and resin content have been procured for use in further studies to obtain a better understanding of the factors influencing comfort. (S2 1-241(C)).

B. Exploratory Chemical and Physical Investigations

1. Exploratory Chemical Modification of Cotton Cellulose. The exploratory research project on the crosslinking of various physically modified crystalline forms of cotton has been terminated. Recent work has shown that the use of plied yarn in a fabric is of major importance in the high strength retention during crosslinking afforded by premercerization. Very high breaking and tearing strength retention during wash-wear treatment of cotton fabric was obtained by fabric premercerization at constant dimensions when the fabric was woven of 2-ply yarn of the proper twist. The fabric mercerization at constant dimensions was almost as effective as yarn mercerization and is much simpler. Yarn mercerization at 3% stretch results in high luster along with high strength in the resin-treated fabric. It has been found that the effect of slack mercerization and restretching does not depend on changing the cellulose crystal lattice; reorientation caused by swelling and stretching must be the essential factor. Other experiments, in which yarns were swollen slack and restretched in benzyltrimethylammonium hydroxide and then crosslinked with DMEU, established that neither degree of crystallinity nor degree of accessibility of cotton are factors in determining the strength retained during crosslinking. By contrast, the degree of orientation obtained during restretching of the highly swollen yarns did correlate with the strength retained after crosslinking. (S2 1-210).

In research to develop improved methods of etherifying cotton cellulose, a variety of commercially available polychlorinated hydrocarbons have been successfully used to etherify and crosslink cotton yarn. When applied under alkaline conditions to slack yarn, bis-chloromethyl benzenes and xylenes were found to impart little strength loss to the cotton. Among other agents investigated, hexachlorocyclopentadiene shows particular promise. Yarns treated with this agent had weight gains up to 18-19%, breaking strength retention of 96%, and an elongation at break double that of untreated yarn. A high degree of crease recovery has been obtained by using disulfatomethane salts to etherify cotton to form methylene crosslinks. Relatively small amounts of combined formaldehyde were needed in relation to the crease recovery obtained. N-methylolacrylamide was successfully used in a delayed curing process to produce wash-wear cotton fabrics which under some conditions show considerable resistance to chlorine bleaches. Research on chemically activated cottons as a means of obtaining new cellulose ethers will be conducted. (S2 1-219).

Fundamental investigations of spatial and structural effects of reversible and conventional crosslinks in cotton have been initiated under a new project. An approach for studying the spatial aspects of reversible crosslinking in cotton has been demonstrated. Paired and random placement of crosslinking reaction sites (p-aminophenyl groups) on cotton fabrics was achieved by reaction with a difunctional reactive dye (Remazol Black G) and a monofunctional reactive dye (Rhodazol Yellow 944), respectively, followed by acid reduction of the azo groups in the dyes to remove the chromophoric group. A comparison of the extent of crosslinking on both fabrics after diazotization and coupling (crosslinking) with a bridging reagent showed that the paired reaction sites crosslinked more readily than did those placed in a random

fashion on the cellulose chain. A significant finding was that a variation of only about 10 Angstrom units in crosslink length could be tolerated. Only small changes in wrinkle recovery and other textile properties were noted at the low degrees of substitution achieved. A search for smaller and possibly more reactive reversible crosslinking agents which would effect higher degrees of substitution and more pronounced wrinkle recovery effects will be made. (S2 1-261).

An exploratory investigation of reversible chemical reactions to obtain information basic to the development of a commercially feasible reversible crosslink has been initiated in cooperation with the Cotton Producers Institute. Thermally reversible crosslinking has been related to thermally reversible creasing, the underlying objective of the project. The limits of practical cotton creasing were established as 200°C. for 30 seconds at 0.2 lb./sq. in. iron pressures. A screening method utilizing the Differential Scanning Calorimeter was developed for determining the thermal stability and transition temperature related to linkages chemically attached to cotton cellulose. Thermal stabilities for a series of chemically modified cottons ranged from 160°C. (acetylated) to 344°C. (formaldehyde-treated). An investigation of N-phenyl and substituted N-phenyl carbamylated celluloses showed that electron withdrawing groups on the aromatic nucleus increased the thermal stability of the carbamate linkage and the electron releasing groups decreased the thermal stability. The N-phenyl type having electron releasing groups appears promising since these derivatives have transition temperatures as low as 230°C. Basic information obtained in this research will facilitate the synthesis and development of thermally reversible crosslinks. (S2 1-258).

Exploratory research on the crosslinking of chemically modified cotton to obtain cotton fabrics with an optimum combination of resiliency and thermoplasticity is in progress at the Textile Research Institute under a research grant. Initial work has been concentrated on methods of chemical modification to impart thermoplasticity to cotton and the characterization of the modified cottons. Benzylated and acetylated cottons have been investigated; and benzoylated cotton has been prepared, and reduction of the benzoyl groups to benzyl ether groups is being explored. The research has indicated that the thermoplasticity of chemically modified cottons can be detected and evaluated by use of differential thermal analysis. Gas chromatographic procedures are proving useful for characterization of hydrolysis products of the modified cottons. Crosslinking studies are being initiated. (S2 1-240 (Gr.)).

The major objectives of the fundamental study of reactions between epoxy compounds or their halohydrin precursors and cotton cellulose have been achieved. Basic information concerning mechanisms of ring openings of several diepoxides has been obtained, conditions required for reacting cotton with halohydrin precursors of epoxides have been established, and various types of substituents such as quaternary groups, oleophobic groups, and unsaturated groups have been added to cotton via epoxide reactions.

The research findings should aid in the development of new and improved methods for the chemical modification of cotton to impart desired end-use properties. (S2 1-216).

The contractor (General Aniline and Film Corporation) has completed experimental work in the research on reaction of acetylene and related compounds with cotton cellulose. Vinylated cotton fabrics and yarns of various degrees of substitution (D.S.) were prepared. Above a D.S. of 0.7 severe degradation of the fibers resulted. Discoloration and a slight stiffness were observed in samples vinylated to a D.S. above about 0.3-0.4. Samples with a D.S. of 0.05 and below were found to be soluble in cuprammonium hydroxide solution. Viscosity determinations indicated molecular weights of 43,000 to 137,000 which were considerably lower than the 430,000 molecular weight of the starting cotton. All samples with higher D.S. values were insoluble in the reagent indicating at least a small amount of crosslinking. Most samples had breaking strengths which were 60-85% of that of the controls, and they showed 20-50% elongation-at-break. Further chemical reactions conducted at the vinyl group should result in a variety of interesting modified cottons. (S2 1-199(C)).

In cooperation with the International Lead Zinc Research Organization, research to impart useful properties to cotton through application of lead compounds and other metal compounds has continued. Efforts to scale up the reduction of lead salts to free lead on cotton fabrics were successful. Application of polymeric coatings increased the physical and chemical stability of the finish. The fabrics possessed good rot and flame resistance as well as a high sheen. Optimum conditions have also been established for impregnating cotton fabrics with metallic silver and silver-copper by reduction of ammoniacal solutions of the metal salts with hydrazine and with sodium borohydride. Samples containing up to 50% metallic lead have been obtained without loss in breaking strength; these, in particular, are evoking industrial interest at the present time. However, the silver and silver-copper treated fabrics possess better rot resistance, showing good resistance after four weeks of soil burial, and also have good flame resistance. Cotton fabrics treated with thiomethyl- and thiopropyltriphenyllead have shown good rot resistance after 9 months of soil burial, and those treated with N-(tributylplumbyl) imidazole, triphenyl lead acetate, triphenyl lead laurate, and lead mercaptobenzothiazole are exhibiting good resistance to rot after four weeks of burial. The research will continue along present lines. (S2 1-232).

Recent exploratory work on the chemical modification of cotton fabrics using reagents in the form of fogs or aerosols has involved the spray application of a thermosetting resin to one side of a fabric and a thermoplastic resin to the other side in attempts to enhance the wash-wear properties of the textiles. Some strike-through was noted, but it is believed that the mobility of the treatments can be controlled with thickening agents. The possibility of treating cotton rawstock with wash-wear and other resins for

special properties, then blending these fibers with untreated cotton is also being investigated as a possible means of reducing abrasion damage in resin treated cotton fabrics. (S2 1-247).

Based on exploratory screening experiments by the contractor (Gagliardi Research Corporation), three promising reaction systems for chemical modification of cotton by treatment with reagents in the vapor phase have been selected for more intensive development. Included are: (1) polymerization onto cotton of vapors of chlorosilane monomers, which imparts a high degree of water repellancy through a preferred polymer orientation; (2) the cross-linking with formaldehyde of cottons preimpregnated with urea and other nitrogenous compounds, which yields products having both good wet and dry crease resistance; and (3) graft polymerization onto cotton of the perfluoroacrylates, which imparts oil and water repellancy. These superior functional properties, coupled with better uniformity and lower processing cost, indicate that promising industrial vapor phase techniques can be developed. A prototype vapor phase reactor has been modified for adaptation to new vapor phase reagents, providing for increased flexibility and pointing the way to the requirements of a commercial design. (S2 1-231(C)).

A fundamental study of the preparation and properties of phosphonitrilic and phosphoryl chloride derivatives having potential for reaction with cotton is being conducted under a P. L. 480 grant at Birkbeck College of University of London. The research is an outgrowth of work conducted under P. L. 480 project UR-E29-(20)-35, now expired, under which the chemistry of these interesting inorganic compounds was placed on a sound, systematic basis. Progress is being made in the synthesis, separation, and purification of selected compounds of this type which have configurations that suggest ability to react with cotton cellulose, and in the attachment of cellulose reactive side chains to the phosphazene by replacement of halogens. Interesting compounds have been prepared that possess a high degree of thermal and hydrolytic stability. Polymers containing nitrogen and phosphorus which have good adhesive properties have also been proposed. Fundamental information has been obtained that is useful in understanding the reactions of phosphazene. Certain of the compounds are expected to be useful in the treatment of cotton to afford improved properties, such as flame resistance, ablative and wash-wear properties. (UR-E29-(20)-55).

2. Chemical Reactions Initiated in Cotton Cellulose and Chemically Modified Cotton by High Energy-Radiation, Light, and Heat. Evaluations of the properties of cotton yarns and fabrics grafted with polyvinyl acetate, polyacrylonitrile, and polymethyl methacrylate by the post-irradiation technique have been completed. Vinyl acetate grafting produced marked improvements in flat and flex abrasion resistance of fabrics even at low graft polymer contents. Polyacrylonitrile grafted fabrics did not exhibit marked improvements in abrasion resistance until high vinyl polymer contents were attained (>25%). The polyvinyl acetate-cotton copolymer exhibited the greatest degree of thermoplasticity. The various grafted fabrics retained almost the same strength and elongation properties as the controls. The

grafted yarns exhibited slight decrease in breaking strength, marked increase in elongation-at-break, decreased breaking stress, and marked decreases in average stiffness. Although the weather resistance of the various vinyl-cotton copolymers was not significantly different from that of untreated cotton, polyacrylonitrile-cotton copolymers did exhibit significant resistance to rot in soil burial tests. Radiochemical yields and the rates of the various grafting reactions were determined. With acrylonitrile and methyl methacrylate the grafting reaction occurred predominantly in the outer cellulose layers of the fiber structure, but with vinyl acetate the grafted polymer was uniformly distributed throughout the fiber cross section. Work is presently underway to isolate the vinyl polymers from the cellulose to which they are grafted in order to determine the molecular weights of these vinyl side chains and to relate these findings to the physical properties of the vinyl-cotton copolymers. (S2 1-195).

Electron spin resonance studies of the free radicals produced in cotton cellulose, cellulose derivatives, and various model compounds by heat, high-energy radiation, and ultraviolet radiation have been initiated. Intramolecular transfer of high energy in purified cotton cellulose has been demonstrated to occur over distances several times greater than the length of the "b-axis" of a cellobiose unit. Preliminary results in the research have shown that the substitution of benzoyl, naphthoyl, and benzyl groups on cotton cellulose radiation protects the molecule; also, indications are that substitution of benzoyl groups may increase the weather resistance of cotton. Energy transfer in fibrous cotton cellulose is obviously related to its thermal, photochemical, and radiochemical resistances. It would appear that it may be possible to direct this intramolecular energy transfer to localization in chemically substituted groups from which the energy can be dissipated without cellulose degradation. (S2 1-270).

3. Mechanisms, Rates and Catalysis of Reactions of Cotton Cellulose and of Chemically Modified Cotton. In a fundamental study of mechanisms of cellulose etherifications, rates of reaction between cotton and additional N-methylolurea derivatives currently used commercially in a delayed cure process have been investigated. Effects of catalyst and of time of storage of treated fabrics at various low temperatures (25 to 65°C.) were studied, as well as the effects of N-substituents and C-substituents on the ureas. The research seeks a sound scientific basis for a system which can be used at room temperature for treatment of fabric and which will also permit storage of the treated fabrics under warehouse conditions for long periods of time before use in garment manufacture. Investigation of the chemical kinetics of cellulose etherifications is continuing. (S2 1-196).

Research on the partial esterification of cotton with long-chain monobasic acid chlorides in nonaqueous media has shown that fabrics with high wet and dry crease recovery can be produced by this process even at low levels of esterification (degree of substitution < 0.15). The crease resistance properties imparted to the fabrics vary not only with the chain length of the acid used, but also with substituents and degree of unsaturation in the fatty

acid-moiety. The presence of hydroxyl groups or unsaturation in the fatty acid-moiety improves both the wet and dry crease recovery properties of the finished fabric as compared with cotton fabric finished to a like degree of substitution with a saturated fatty acid chloride of the same chain length. Increase in wet crease recovery angles by presence of unsaturation is even more pronounced than the increase in dry crease recovery angles. These findings are of both theoretical and practical importance. Partial esters of cotton will be prepared by various methods of esterification, and fabric properties of esters of like degree of substitution will be compared. (S2 1-233).

A study of the oxidation of cotton and crosslinked cotton by hypochlorite, hypobromite and other agents commonly used in bleaching cotton products is being conducted at the University of Commerce and Industry of the State of Israel. The P. L. 480 project under which the work is being done is an outgrowth of an earlier project, UR-A10-(20)-4, now completed. Basic information is being developed in early phases of the work concerning the conditions governing the oxidation, degradation and yellowing effects that occur on mild oxidation of cottons treated with crosslinking agents commonly used in the easy-care finishing of cotton fabrics. The information obtained in this research is expected to be useful in improving the characteristics of cottons, especially fabrics treated for easy-care properties for various end uses. (UR-A10-(20)-50).

4. Exploratory Physical Investigations on Cotton. Contract research at Macrosonics Corporation on treatment of cotton fibers with sonic energy is underway. The contractor has designed, constructed, and tested both single and dual face transducer elements for irradiation of cotton samples in liquid media, and has developed analytical instruments for accurate measurement and continuous recording of various operational variables. Preliminary trials were conducted using these transducer elements to irradiate small cotton samples in water with low power acoustic energy over a wide range of frequencies for short periods of time. Under these experimental conditions, negligible effects on moisture regain, tensile strength, and fiber density were noted. However, treatment of larger samples (25 g.) of cotton at two selected frequencies (40 KCS and 800 KCS) for longer times (1 and 1-1/2 hrs.) revealed some small changes with regard to tensile strength, dye absorption, and moisture regain properties. Other fiber properties are currently being investigated. The exploratory research will be expanded to include irradiation in gas media. (S2 1-222(C)).

Under a P. L. 480 project at the Chalmers University of Technology in Gothenburg, Sweden, a basic investigation of the behavior of cotton fibers when subjected to aerodynamic forces is being carried out. Apparatus has been designed which permits the taking of high-speed motion pictures of separated cotton fibers traveling in air streams of different velocities. Conditions and designs are being studied which will cause the fibers to become parallelized through aerodynamic forces exerted by the flowing air stream. Fundamental information of the type being developed in this research is

prerequisite to the design considerations in devising totally new and unorthodox methods for the processing of cotton into useful textile products. (UR-E26-(20)-6).

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INTERRELATIONS AMONG FIBER, YARN, AND FABRIC PROPERTIES

Southern Utilization Research and Development Division, ARS

Problem. The intense competition in today's textile markets is placing increasing demands upon cotton producers and processors for high quality products tailored to meet specific use requirements. Improvements in the quality of processed products and lower costs of mechanically processing cotton into yarns and fabrics are needed to satisfy consumer demands and maintain cotton markets. For example, information is needed to determine the effect of the important fiber properties and combination of fiber properties of cottons on yarn and fabric properties and processing performance to obtain the maximum utilization potential from cottons of different fiber properties and to provide guidance for cotton breeders in developing strains having more desirable fiber properties. Improved mechanical processing methods are needed to attain maximum yarn uniformity and the resultant improvements in the general quality level and processing efficiency of all types of cotton products. New and improved methods and instruments for measuring the physical and chemical properties of cotton are needed to guide processing research in developing new and improved products.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving cotton technologists, textile technologists, textile engineers, physicists, statisticians, and mathematicians engaged in research to develop fundamental information and improved processing procedures in order to improve the quality and lower the cost of cotton products during the mechanical processing of cotton fibers into yarns and fabrics.

Research to determine the effect of fiber properties on processing efficiency and product quality is carried out at New Orleans, Louisiana. Additional research of this type is being conducted under contract at Auburn Research Foundation, Inc., Auburn, Alabama: to determine optimum processing procedures for cotton differing in tensile and elastic properties and relate these properties to mechanical processing performance, yarn, and fabric properties. Cooperation is maintained with cotton merchants and textile mills; the Crops Research Division, ARS, and the Cotton Division, C&MS, specially on the procurement of cotton of known history with special fiber properties; and the Market Quality Research Division, ARS, to insure coordination of effort in related research. Research on development of new and improved methods and instruments for measuring the physical and chemical properties of cotton, and evaluating the processing characteristics of cotton, is carried out at New Orleans, Louisiana. Also, contract research is being conducted at Stanford Research Institute, South Pasadena, California, on development of a method for counting neps in cotton at various stages of textile processing; and on development of a research instrument for accurately and automatically determining length, length distribution and diameter of cotton fibers.

Other research on effect of fiber properties on processing efficiency and product quality is in progress under grants of P. L. 480 funds to the following foreign institution: Ahmedabad Textile Industry's Research Association, Navrangpura, Ahmedabad, India, for investigation of means to minimize fiber hooked ends in cotton card and drawing slivers (project duration - 4 yrs.,) and for an investigation of factors affecting drafting in the direct sliver spinning system (project duration - 5 yrs.). Research relating to development of new and improved methods and instruments for measuring physical properties of cotton is in progress under grants of P. L. 480 funds to the following institutions: German Research Institute for Textile Industry, Reutlingen-Stuttgart, West Germany, for the development of an apparatus for counting neps in cotton card web (project duration - 4 yrs.); and Lodz Polytechnic College, Lodz, Poland, for an investigation of the mathematical and theoretical aspects of the relationship between the fiber length distribution of cotton specimens before and after sample preparation (project duration - 3 yrs.).

The Federal in-house scientific effort devoted to research in this area totals 14.5 professional man-years. Of this number 12.6 is devoted to investigations of effect of fiber properties on processing efficiency and product quality and 1.9 to development of new and improved methods and instruments for measuring the physical properties of cotton. The contract research involves an additional 3.9 man-years, 1.1 being on effect of fiber properties on processing efficiency and product quality, and 2.8 on development of new and improved methods and instruments for measuring physical properties of cotton. P. L. 480 research involves 4 grants, of which 2 are on effect of fiber properties on processing efficiency and product quality and 2 on development of new and improved methods and instruments for measuring physical properties of cotton.

The following lines of work were terminated during the year: (1) Large-scale spinning evaluation of the effect of fiber properties and spinning variables on yarn properties and end breakage during spinning; (2) Determination of relationship between the cohesion of cotton fibers and other physical properties of fibers, rovings, and yarns, as a step in improving product quality and processing efficiency (P. L. 480 project) (under Effect of Fiber Properties on Processing Efficiency and Product Quality); and (3) Development of test methods for stretch cotton textiles for use as a guide in producing better cotton stretch yarns and fabrics (under Development of New and Improved Methods and Instruments for Measuring the Physical and Chemical Properties of Cotton).

PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given under Area 1)

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Effect of Fiber Properties on Processing Efficiency and Product Quality

1. Effect of Cotton Fiber Properties Such as Length, Strength, Fineness and Elongation on Fabric Properties and Processing Performance.

In research to determine the simultaneous effect of pertinent fiber properties and combinations of fiber properties on yarn properties and spinning performance to provide guides for obtaining maximum utilization of cottons of varying fiber properties, the initial investigations on the effect of back drafts, tensor settings, and total drafts on yarn properties and end breakage using the SRRL Accelerated and 720 Spindle Hour Tests have been completed. It was found that end breakage decreased curvilinearly as back draft decreased from 2.7 to 1.3, regardless of total drafts, tensor setting, or yarn number, after which end breakage increased as the back draft was further reduced from 1.3 to 1.02. Generally, a back draft of 1.3 produced yarns of superior yarn strength, elongation and uniformity and minimum end breakage. Evaluations of three major drafting systems have shown that draft distribution is an inherent characteristic of individual drafting systems, each having its own optimum back draft to produce the best combination of end breakage and yarn properties. This finding should be helpful to the textile industry in increasing spinning rates and maintaining yarn quality at acceptable levels. A back draft of 1.3 and a 5 mm. tensor setting have been selected for use in spinning performance evaluations of the 150 experimental cottons accumulated for this research. The cottons have been divided into three groups based on fiber length; the medium length group (1.06" to 1.20") of 79 samples will be processed first using the SRRL 720 Spindle Hour and the Accelerated Spinning Tests. (S2 1-207).

Large-scale spinning evaluations of factors affecting end breakage in spinning have been completed by the contractor (Auburn Research Foundation). The research findings have prompted one manufacturer (the cooperating mill) and probably others unknown to us to place emphasis on blending their cottons on the basis of fiber length distribution, with less emphasis being placed on Micronaire reading or fiber strength. This has led to a better utilization of fiber properties and permitted the use of higher spindle speeds and production with a resultant reduction in the costs of manufacture. (S2 1-178(C)).

In research conducted under a recently completed P. L. 480 project at the Juan de la Cierva School of Technical Investigations, Barcelona, Spain, a study was conducted of the relationships between the cohesion of cotton fibers and other physical properties of fibers, rovings and yarns. The cohesion of cotton fibers affects the roll settings, roll pressures and twists to be used in producing yarns of optimum quality. An improved apparatus was developed for measuring minimum twist of cohesion and through its use the main laws governing the minimum twist of cohesion of cotton rovings and yarns in connection with testing conditions (length and tension) and fiber parameters (length and micronaire) and yarn parameters (number of fibers per cross

section and twist) were determined. It was established that treatments that affect the surface properties of cotton fibers alter the cohesion between fibers and hence the minimum twist of cohesion. This, in turn, affects the settings used in drafting. Information developed in this project should permit the relatively rapid and simple measurement of force of cohesion to be used in predicting the spinning efficiency and yarn properties of cottons of differing fiber properties. (UR-E25-(20)-2).

2. Improved Processing Procedures to Obtain Maximum Utilization of Native and Modified Cottons. Studies of principles and procedures for optimum blending of cottons of varying fiber properties have continued. Relatively large samples of raw stock of three pairs of cottons (low and high short fiber contents, Micronaire readings and fiber bundle strengths) were blended in equal amounts and processed by two respectively different procedures (maximum blending; minimum blending) and spun into yarns. Differences in uniformity between matched pairs of samples (from good mix vs. poor mix) of card, first, and second drawing slivers were too small to permit drawing conclusions. There was a decrease in the quality of yarns--as reflected by measures of length uniformity, gross imperfections, skein strength and variability of skein strength--in the following order for the various schedules of mixes: (1) short fiber content differences (good mix), (2) short fiber content differences (poor mix), (3) Micronaire reading differences (good mix), (4) Micronaire reading differences (poor mix), (5) fiber bundle strength differences (good mix), and (6) fiber bundle strength differences (poor mix). End breakage in spinning increased in the order (1), (3), (5), (2), (4), and (6) of the above listing. This grouped samples from the good mixes as being better than those from the poor mixes. For each of the three aforementioned pairs of blends, one blend was given one picking process, carded, and made into roving; the other was given two picking processes, carded, two drawing processes, and made into roving. Analysis of the appropriate fiber property on sequential lengths of samples showed that the latter "conventional" process--as opposed to the simulated "shortened" process--caused significant deterioration in length and length uniformity and increases in short fiber content; caused increases in Micronaire reading; and produced little, if any, change in fiber bundle tenacity from carding through roving. Elimination of drawing processes as in the "shortened" procedure contributed to lower yarn properties and spinning performance. (S2 1-234).

Contract research was recently initiated at Auburn Research Foundation to determine optimum processing procedures for cotton differing in tensile and elastic properties and relate these properties to mechanical processing performance, yarn, and fabric properties. Based on fiber property tests, the contractor has selected 18 bales of 1-1/16" cotton varying appreciably in strength and representing three levels of fiber-bundle elongation (5.1, 6.8, and 8.5 percent, average) but having comparable fiber lengths and Micronaire readings. Processing tests on these samples have begun. Suitable 15/16" cottons are being collected for the next phase of the research. (S2 1-242(C)).

New research is in progress to determine the effect of high production carding on fiber length distribution and fiber hook formation in card sliver, and to establish improved drafting procedures required for maximum removal of fiber hooks for carded and combed yarns. In preliminary tests with a 1-1/16" Delta cotton, it was found that increases in carding rate caused the amount of trailing (majority) hooks to decrease and leading (minority) hooks to increase. This results in: (1) a net increase in fiber hooks, and (2) a decrease in difference between leading and trailing hooks as production rate increases. This difference between the leading and trailing hooks was generally smaller for low than high cylinder speeds. It was more pronounced for the optimum drafting direction (majority hooks trailing at first and second drawings, leading at roving, and trailing into spinning) than for the conventional direction. The spinning data indicated that the amount of hooks entering spinning and end breakage were highly correlated. Larger-scale processing experiments are in progress. (S2 1-274).

In the spinning of cotton yarns, assemblies of fibers are simultaneously drawn out and twisted. The drafting forces exerted during the spinning operation affect the quality of the resulting cotton yarns. Research has been completed under a P. L. 480 grant at the Juan de la Cierva School of Technical Investigations in which an investigation was made of the effect of various factors in spinning, such as drafting speed, roving twist, apron opening, roll setting, etc., on drafting force in the drafting zones of high draft spinning equipment, and how the drafting forces affected yarn quality. An apparatus was developed for measuring the drafting forces in the front and rear drafting zones. A surprising result of the research was the finding that increases in drafting speed increased the drafting force as well as yarn strength. It was also shown that the parameters that afforded the highest drafting force (without fiber breakage) yield the optimum yarn quality. It was found that with small tensor setting, changes in back draft had less effect on yarn strength and uniformity than with large tensor setting; also tensor setting had less effect on yarn strength as back draft was increased. The investigation provided basic information that will be of assistance in developing improved drafting systems, and in making more efficient use of existing systems. (UR-E25-(20)-13).

An investigation is underway of means to minimize fiber hooked ends in cotton card and drawing slivers under a P. L. 480 project at the Ahmedabad Textile Industry's Research Association in India. Ends breakage in the processing of cotton is related to the presence of hooked ends in the fibers making up sliver. Conventional processing organizations tend to remove hooked ends, but in abridged processes such as direct spinning, the fewer drafting processes between carding and spinning allow more fiber hooks to remain, and hence adversely affect spinning efficiency. Consequently, work under this project is expected to be of use in facilitating direct spinning and improved cotton processing through means to minimize the amount of fiber hooks in card or first drawing sliver. (UR-A7-(20)-51).

B. Development of New and Improved Methods and Instruments for Measuring the Physical and Chemical Properties of Cotton.

1. Development and Adaptation of Instrumental Techniques for Measuring the Changes Imparted to Cotton by Chemical and Mechanical Processes. The research project to develop test methods for stretch cotton textiles has been terminated. Comparison of five different procedures for determining recovery of stretch cotton textiles showed that each method causes a different degree of deformation and, therefore, gives a different value for recovery. The research has shown that in testing stretch fabrics it is desirable to obtain recovery data at several different points of extension. This procedure is necessary to compare fabrics with different stress-strain characteristics and when the end-use is not definitely established. The Static Extension Test, one of the methods investigated in the research, has been reported by others to correlate well with wear tests run on man-made fabrics, but a definite procedure for this test has not been widely adopted. Since the Static Load Test gives somewhat similar results while requiring less material and effort, this test is recommended for evaluating cotton stretch fabrics pending adoption of a standard method. In one phase of the work, a procedure for determining strength, elongation, and recovery of stretch cotton lace was developed. (S2 1-212).

Research to develop more reliable methods of appraising abrasive damage on all-cotton wash-wear fabrics has been initiated. Initial experiments showed that the same type of untreated cotton fabrics which were desized, scoured, and bleached at different times did not exhibit the same flex abrasion resistance. This has been attributed to unequal amounts of residual waxes remaining in the various fabrics after the desizing, scouring, and bleaching steps. Good correlation between flex abrasion resistance and elongation of the fabrics was generally found. However, there appears to be an inverse relationship between flex abrasion resistance and the breaking strength and energy to rupture. Very good correlation between flex abrasion resistance and edge abrasion resistance was obtained when fabrics which had been treated with formaldehyde without use of softeners were tested. The research will continue along present lines. Effects of softeners on abrasion resistance will be investigated. (S2 1-275).

Satisfactory progress is being made by the contractor (Stanford Research Institute) toward development of a method and equipment for rapidly and accurately counting neps at various stages of textile processing. Theoretical evaluations and exploratory research have indicated that the following two approaches appear feasible: (1) a technique based on light scattering by neps and cotton mats, and (2) a technique involving use of colored aerosols for labeling neps. Apparatus has been designed and is under construction for experimental use. The work is being delayed to some extent by difficulty in obtaining delivery of specially made, precision ground lenses and other components for the light scattering unit. (S2 1-229(C)).

P. L. 480 research is continuing at the German Research Institute for Textile Industry to develop an apparatus for the rapid and automatic counting of neps in cotton card web by means of light reflectance and detection. Principles developed through studies using a prototype instrument that scans a sample of card web are now being extended in two promising approaches toward the problem of measuring neps in the running web on the full scale card. The approaches involve the use of some of the principles of television for scanning the web and clever, sophisticated electronic instrumentation has been devised for evaluating these approaches. The development, if successful, is expected to be of great value to cotton processors since it would provide rapid means for following, and perhaps automatically controlling, an important processing variable that affects cotton fabric quality. (UR-E10-(20)-2).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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¹/ Publication resulting from research under grant of P. L. 480 funds to the foreign institution.

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^{1/} Publication resulting from research under grant of P. L. 480 funds to the foreign institution.

NEW AND IMPROVED TEXTILE MACHINERY

Southern Utilization Research and Development Division, ARS

Problem. Blending cotton is an urgent problem in the textile industry now that research has clearly shown the effects of fiber properties on processing efficiency and product quality. Present methods do not permit a homogeneous blend, require excessive floor space and have low production rates. Improvement in carding equipment and procedures is another area in need of research. Due to inadequate methods of feeding, high production cards cannot be utilized to maximum advantage in reducing costs and increasing quality of textile products. The modern cotton mill utilizes ten or more processing stages and, compared to manufacturing systems for competitive products, an excessive amount of labor. The development of a radically new system for processing cotton offers an opportunity for major improvements in strength, uniformity and other functional properties of cotton products, and for substantial savings in manufacturing costs through less damage and waste of spinnable fiber, and through reduction in equipment investment, space and labor.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving mechanical engineers, physicists, and cotton technologists engaged in research to design and develop new and improved equipment for processing cotton into higher quality, lower cost consumer products.

Research to develop improved mechanical processing machinery, for opening through carding, is conducted at New Orleans, Louisiana. This work includes the development of experimental machines and pilot scale machines for evaluation under pilot-plant conditions, and subsequent development of plans for scaling up successful units into practical, commercial size equipment. Current research involves the development of a bale-breaker blender for opening and blending cotton, improved methods of feeding the card, and the development of an improved method and apparatus for removing short fibers and improving fiber parallelization at textile carding machines. Close cooperation is maintained with cotton textile machine manufacturers and cotton textile processors in the establishment and dissemination of engineering specifications for the commercialization of new and modified processing equipment. Additional research in this area is being conducted under contract at General Applied Science Laboratories, Inc., Westbury, L. I., N. Y. on the aerodynamic separation of lint cotton into individualized fibers to provide information needed for improving cotton textile processing equipment.

The Federal in-house scientific effort devoted to research in this area totals 15.4 professional man-years. All of this effort is on the development of improved mechanical processing machinery - opening through carding. The contract research involves an additional 1.1 man-years, in the field of improved mechanical processing machinery-opening through carding.

PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given under Area 1)

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Improved Mechanical Processing Machinery - Opening Through Carding

1. Equipment for Blending Cottons of Different Fiber Properties to Produce Improved Cotton Textiles. Evaluation tests on the pilot-size SRRL Bale-Opener-Blender for opening and blending cotton have been successfully completed. They indicated that processing through the machine causes no damage to the properties of the cotton fibers. A new feed system which supplies a continuous sandwich bale of cotton to the blender was installed on the pilot machine and measured up to expectations. This feed system has proven to have several advantages over the previously used truck feed system which supplied individual sandwich bales: (1) it enables continuous operation without downtime for loading, (2) it provides increased cotton capacity, resulting in less loadings per shift, and (3) since no bale ends need be processed, it eliminates end-of-the-bale difficulties previously encountered. Design of a full-size blender is underway and progressing satisfactorily. The new feed system is being incorporated into the design. Necessary equipment and supplies for construction of the full-size machine is being procured. (S2 1-252)

2. Improved Methods of Feeding the Cotton Card to Produce Higher Quality Textile Products. Research has continued on the two new approaches and mechanisms for feeding the cotton textile card: (1) the Lap-Drafting Apparatus, and (2) the Precarding Apparatus. A full-size Lap Drafter has been installed on a laboratory carding machine for further development. Individual variable-speed drives have been provided for all units of the Drafter to enable establishment of the best operating conditions. Information previously obtained with the bench-model Drafter will be used as a guide. The experimental model of the Precarding Apparatus also has been installed on a laboratory card so that the thin layer of cotton from the apparatus is fed directly into the card. Since the Precarder is flexible with respect to extent to which cotton is worked, thickness of layer produced and production rate, it will be possible to test a wide range of machine variables and operating conditions as to their effect on feed conditions and the quality of the card web. One observation to date is that the apparent quality of the card web changes very little as the quality of the layer fed to the card is varied over a wide range for the same cotton. Research under a new project will be concerned with the development and evaluation of prototype machines from the Lap Drafter and the Precarder. (S2 1-215)

3. Equipment for Removing Short Fibers from Cotton. Investigations of devices for removal of short fibers from cotton have continued. The previously developed counter-rotating cylinder electrostatic fractionator has been modified to enable increasing production rates while maintaining short

fiber removal. On an eight-inch-wide unit, the short fiber removal was 33 percent at 1/2 pound per hour production. The research has shown that, contrary to research reports of others, electrostatic forces applied to cotton fibers can cause the long fibers and short fibers to act differently, and can serve as the basis of devices for fractionating cotton fibers into long and short length groups. Also, preliminary investigations with a mechanical fractionating device have suggested its possible application to the development of a means of removing short fibers and improving fiber parallelization at the textile card. To achieve the latter objective, promising leads from the research will be applied under a recently initiated project. The initial approach will involve a mechanical system for parallelizing the fibers and continuously combing the output web of the card. The device is currently being designed and constructed, preparatory to installing it on a laboratory card. (S2 1-164 (Rev.), S2 1-273)

4. Aerodynamic Systems for Separating Lint Cotton into Individualized Fibers. The contractor (General Applied Science Laboratories, Inc.) has continued investigations of the application of aerodynamic forces for individualizing cotton fibers. An analysis has been made of the separation of cotton fibers from air by means of a branching canal. By finding the streamlines of the air and the trajectories of the lint particles, the ratio of the percentage of the upstream lint extracted can be found and an efficient geometry determined. An analysis has also been made to determine the forces necessary to extract a cotton fiber from a clump of fibers. A significant achievement was the development of equations relating aerodynamic parameters to the separation of clumps of cotton into individualized fibers. These equations will be a worthwhile tool to aid research and industry in designing better equipment for producing cotton textiles with improved properties. An investigation is also in progress to study the unsteady motion of tangled fibers resulting from sudden decompression in a dilation chamber. Research under this contract has disclosed the fundamental mechanism of forces involved in fiber disentanglement and the complexity of the problem. (S2 1-204(C))

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Improved Mechanical Processing Machinery - Opening Through Carding

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IMPROVEMENT OF WASH-WEAR PROPERTIES

Southern Utilization Research and Development Division, ARS

Problem. Garments which are wrinkle resistant and suitable for wash-wear use are increasingly important to the consumer. Although much progress has been made toward securing this market for cotton, much additional information is needed to hold and expand cotton's share of this enormous market. According to recent industry estimates 1.2 million bales of cotton are used annually which would not have been utilized except for the wash-wear development. Projected estimates indicate that in the future most apparel and almost all household textiles will be given a wash-wear or a minimum-care finish. Research on synthetic fabrics is mainly aimed at this lucrative market and is several times greater than the entire utilization effort on cotton. At the same time chemical firms are reducing their research in the development of cotton wash-wear finishes. Promotional advertising claims on cotton wash-wear products have exceeded the actual achievement, and many problems remain to be solved. Much fundamental information is needed to explain mechanisms of the reaction of cotton with crosslinking agents as a basis for the development of new and better wash-wear finishes and for the improvement of present processing techniques. Much applied information is needed which, while essential to the maximum utilization of cotton, is generally beneficial to all processors and therefore comparatively unattractive financially to individual companies. Areas in which research is needed to improve wash-wear cottons include processing techniques, fabric appearance, durability, and comfort. Fabric appearance involves the ability to dry smoothly, resistance to wrinkling or mussing during wear, resistance to dry, wet, and oil soiling, introduction of durable creases as desired, dimensional stability and elimination of seam pucker. Durability involves tensile and tearing strength and abrasion resistance in the finished fabric or garment, as well as resistance to abusive laundering, particularly bleaching and souring. Comfort involves moisture absorption during use, elimination of odor on storage or wearing and, in certain cases, stretchability of fabric.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, physical chemists, analytical chemists, physicists, microscopists, chemical engineers, mathematicians, cotton technologists, textile technologists and textile engineers, engaged in both basic and applied research on wash-wear finishing and improvement of wash-wear properties of cotton. Informal cooperation is maintained with textile finishers, chemical manufacturers, and textile research institutes in connection with the research.

Basic and exploratory research on wash-wear finishing of cotton is conducted at New Orleans, Louisiana. This research is designed to give a better understanding of the chemical reactions and physical changes taking place in wash-wear finishing and the crosslinking of cotton in general. It also

seeks to correlate the properties of the finished cotton with the nature of the crosslinking agent or other treating agent. Basic studies of the relationship of fiber properties to fabric behavior in wash-wear treatments are also conducted. The results provide a broad and sound foundation for the development of new, practical wash-wear finishes for cotton. Additional basic and exploratory research is being carried out under contract at Southern Research Institute, Birmingham, Alabama, on the development of wash-wear cotton fabric with improved moisture absorptivity by use of reactive swelling agents.

Research on the improvement of smooth drying properties--the essential features of a wash-wear fabric--is conducted at New Orleans, Louisiana. Some important phases of current work involve development of new crosslinking treatments and optimum wash-wear fabric structures; investigation of chemical and mechanical treatments to improve strength, resilience, abrasion resistance; and pilot-plant evaluation of promising laboratory finishes. The Cotton Producers Institute cooperates in and supports research to develop optimal cotton fabric structures for men's trousers and dress suits. Additional research on improved smooth drying properties is in progress under contract at North Carolina State of the University of North Carolina at Raleigh, North Carolina, on the effects of mechanical treatments of fabrics prior to, during and following resin finishing on ease-of-care properties.

Research to develop new and improved processing methods for the production of wash-wear cotton yard goods and garments is carried out at New Orleans, Louisiana. Processing methods are being investigated for the production of wash-wear cotton stretch goods with improved durable creases, shape holding properties and abrasion resistance. Cost estimates for new chemicals and for processing of cotton are made to aid industrial establishment of various research developments. Additional processing research is being conducted under contract at Georgia Tech Research Institute, Atlanta, Georgia, to develop improved cotton sewing thread for wash-wear fabric structures, compatible with existing high-speed manufacturing methods, which will not cause seam pucker, or which will have a markedly reduced tendency to cause seam pucker.

Other basic and exploratory research on wash-wear cotton fabrics is in progress under a grant of P. L. 480 funds to the Swedish Institute for Textile Research, Gothenburg, Sweden, for investigation of the mechanism of crease formation and recovery in ease-of-care treated cotton fabrics (project duration -- 4 years.).

The Federal in-house scientific effort devoted to research in this area totals 32.6 professional man-years. Of this number 11.5 is devoted to basic and exploratory research on wash-wear, 19.1 to research on improved smooth drying properties, and 2.0 to new and improved processing methods. The contract research involves an additional 3.0 man-years, 1.0 being on basic and exploratory research on wash-wear, 0.8 on improved smooth

drying properties, and 1.2 on new and improved processing methods. P. L. 480 research involves 1 grant on basic and exploratory research on wash-wear.

PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given under Area 1)

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic and Exploratory Research on Wash-Wear

1. Basic Studies of Recovery from Wrinkling and Creasing. Basic investigations of the relation of dry and wet recoveries to wash-wear properties have continued. Determinations of tensile recovery and strength of single cotton fibers for several types of modified cottons (formaldehyde-, dimethylolethyleneurea-, monomethylolethyleneurea-, and oleyl chloride-treated) indicate that fibers are seemingly more sensitive but more variable than low-twist yarns for determining the elastic recovery of wash-wear cottons. Loss in breaking strain is proportionally greater in fibers than in yarns especially for the wet formaldehyde treatments. Recoveries due to the pad-dry-cure of yarns are all of the same type. The immediate recovery values reach a maximum near 65% relative humidity. Per crosslink, dimethylolethyleneurea improves recoveries more than does formaldehyde, but formaldehyde-treated cotton crosslinked to 100% total recovery has a minimum immediate recovery at low strains under standard rather than wet conditions. Oleylated cotton, with its greatest improvement being in delayed recovery, is least sensitive to moisture, and has the largest reduction in modulus. Relationships of strain recovery and energy recovery have been confirmed for several additional types of wash-wear treatments. This indicates that energy recovery, which is more easily and rapidly determined than strain recovery, can be substituted for the latter.

More recent work has placed emphasis on the use of torsional measurements rather than tensile recovery measurements. Torsional properties of cotton fibers chemically treated with formaldehyde and with DMEU were determined for several humidities. The technique devised for this work--wherein the single fiber is the support filament of a torsion pendulum--is more promising than tensile recovery measurements for characterizing differences in recovery properties of fibers at low deformations. It has been found that, upon wetting, the rotational amplitude (self-imposed rotations) of the resin-treated fiber is about one-half that of the untreated (alcohol extracted) fiber. Fibers from which the DMEU has been stripped with acid display essentially the same rotational amplitude as untreated fibers. The rotational frequency (recovery time for imposed turns) is about 145% faster for the resin-treated than for the untreated fibers. Low torsional deformations are completely recoverable in untreated cotton and in those resin-treated cottons investigated thus far. Information being obtained in this research on properties at low deformations, and under conditions of apparent complete tensile recovery as indicated by present tensile tests,

could lead to a better understanding of the mechanism of recovery in chemically treated cotton and those treatments which produce the desired mechanical behaviors. (S2 1-262).

In further research on relationships of fiber properties to fabric behavior in wash-wear treatments, it was found that cellulose density as measured by the gradient column technique is decreased by tension during resin curing of scoured materials but increased by tension on slack mercerized. Density decreases as add-on increases. Fabric structure was found to be relatively unimportant in abrasion resistance of resin treated twill fabrics, but type of resin and scouring or mercerizing prior to resin treatment have pronounced effects on the abrasion resistance at comparable wash-wear rating of fabrics. Fabric structure is important in both abrasion resistance and wash-wear rating of scoured fabric before resin treatment. The research studies have revealed the need for more clearly defined relationships between fiber friction and crease recovery when softeners are added. Friction restrains fiber movement in crease formation and hinders recovery after the crease has formed. It has been found that high concentrations of softeners decrease wrinkle recovery of cotton fabrics, indicating a cementing effect. At low levels of softener, wrinkle recovery may or may not be increased, possibly depending on the wax present in the scoured fabric. Since this unexplained behavior is in an area of research of particular importance to wash-wear treatments both in crease recovery and abrasion resistance, it will be investigated further as one phase of a new project concerned with a study of the relation of fiber properties to physical behaviors of mechanically and chemically treated cotton fabrics. Samples required for the research are being prepared. Cottons of three varieties differing in strength and elongation--Hopi Acala, Pima S-2, and Deltapine 15--have been processed into fabrics of different structures, identical for all three cottons. The fabrics are being scoured and portions of the scoured fabrics will be slack mercerized. Both the scoured and the mercerized fabrics will be resin treated with various tensions applied prior to curing. (S2 1-198, S2 1-272).

The research on effects of time and environmental conditions on the rate of wrinkle recovery of wash-wear cotton textiles has been terminated. The greatest difference in rate of wrinkle recovery is found in the first 2.5 seconds of the standard wrinkle recovery test. There is relatively little change in the shape of recovery curves after about 2.5 seconds of recovery time. However, the final level of wrinkle resistance achieved is greatly influenced by such factors as type of laundering and drying, atmospheric humidity and moisture content of the fabric. Laundering, either by home-type or commercial procedures, decreases the wrinkle resistance of wash-wear cottons but does not affect the shape of the rate of recovery curves. The rates of wet crease recovery of four types of wash-wear cottons were similar to those obtained in the standard test atmosphere (70°F. and 65% RH). Long-time creasing (64 hrs.) lowers the initial, standard, and 20-minute crease recovery angles of crosslinked cottons. However, the rate of recovery appears to be essentially unchanged. Wash-wear cottons creased at

one humidity and relaxed at another were found to exhibit different levels of wrinkle resistance than when creased and relaxed at the same relative humidity. The rates of recovery, however, appear to be essentially the same after the initial opening of the test specimen. Hydroxyethylated cotton, a noncrosslinked cotton which is highly swellable in water, has a relatively high wet crease recovery angle. The shape of its recovery curve after about 2.5 seconds of recovery time is essentially the same as observed for cross-linked cottons. (S2 1-203).

2. Basic Investigations to Improve the Properties of Wash-Wear Cottons.

Contract research is in progress at Southern Research Institute to develop wash-wear cotton fabrics with improved moisture absorptivity by use of reactive swelling agents. In initial experiments, cotton printcloth treated with methylolated N,N'-dihydroxyethylenebisacetamide or the corresponding bisurethan was found to have greater moisture absorptivity than samples treated with either dimethylolethyleneurea or dimethylolethyltriazone. The two bisamides will be examined further, and other hydrophilic groups will be applied with crosslinking agents. (S2 1-239(C)).

Research has been initiated to obtain basic information on the properties which are important for resistance to edge abrasion damage in wash-wear cottons, particularly durably creased garments, and to develop methods for improving the resistance of cotton to such abrasion. Initial experiments, in which a number of selected polymers have been applied to cotton fabrics in conjunction with crosslinking agents, have given promising results. It has been found that polymers that improve fabric hand or softness (silicones) generally improve cuff wear life. On the other hand, polymers that are both tough and stiff do not increase resistance to edge abrasion to any extent. Mercerization (either slack or slack followed by restretching) significantly improves wear life (resistance to abrasion) of cotton fabrics treated with almost any wash-wear agent. Lower curing temperatures and use of reactive softeners have also reduced edge abrasion in wash-wear cottons. Special attention will be given to investigation of the use of polymers in combination with mercerization and a wash-wear treatment, and the use of reactive softeners in conjunction with other treatments. (S2 1-260).

B. Improved Smooth Drying Properties

1. Development of Treatments to Improve Strength, Resilience and Other Desirable Properties of Wash-Wear Cottons. The research to produce improved wash-wear cotton through swelling treatments has met with limited success thus far. Although mercerization under conditions which give high swelling retention prior to crosslinking results in increased wet wrinkle recovery of the crosslinked cotton fabric, this approach does not overcome the adverse effects of mercerization itself on wash-wear properties. Use of inert additives, either organic or inorganic, has much less effect on swelling than does the modified mercerization. Phosphoric acid produces a swelling effect equaling or exceeding that from mercerization but produces other adverse side effects. New swelling agents are needed. The importance of

interlamellae regions of the cotton fiber on moisture regain has been confirmed by experiments on viscose. Additives for increasing moisture regain of crosslinked cotton need not be water-soluble or exceptionally high boiling. Studies on specific volume of crosslinked cottons will be made to provide a direct measure of swelling ability. Other work has led to the development of highly active catalysts which will allow the use of cross-linking agents formerly difficult to cure, and the use of milder curing conditions with common agents. The catalysts are made from magnesium chloride and a compound from a wide range of hydroxy or alkoxy substituted carboxylic acids. (S2 1-235).

Investigation of the crosslinking of cotton with new types of N-methylol and related derivatives has continued. An acrylamide-aspartic acid adduct was prepared and found to produce fabrics having intermediate crease recovery angles. Experiments with glycine-acrylamide derivatives showed that 10-12% concentrations were required to produce the best wash-wear fabrics. A phosphonic acid analog of a glycine-acrylamide has been prepared and is being used, after methylolation, in laboratory studies as a crosslinking agent for cotton. It is hoped that this agent will provide flame retardant properties as well as wash-wear properties. Another agent--4,5-dihydroxy-1,3-dimethyl-2-imidazolidinone--looks promising in delayed cure procedures because there is no possibility of formaldehyde release during storage or in use. Hydroxylation of N,N'-ethylenic amides appears to be a new synthesis path for formation of N-methylol type derivatives. It is expected that many such derivatives, which are promising crosslinking agents and are unavailable from normally used synthesis paths, may be obtained in this manner. (S2 1-227).

Research to develop wash-wear finishes for cotton based upon carbamate finishing agents continues to show promise. Dimethylol hydroxyethyl carbamate and dimethylol hydroxypropyl carbamate, two new agents developed in the work, have good potential. Lightfastness of dyed cotton fabrics finished with these agents is markedly better than that of fabrics finished with simple monoalkyl carbamates. With proper finishing conditions the new agents produce durable finishes having good wrinkle and chlorine resistance. Also, the potential cost of the agents is low. They appear to be good agents for deferred cure finishing to produce durably creased, wash-wear cotton garments. Dimethylol hydroxyethyl carbamate is currently being evaluated in wash-wear finishing by several textile finishing companies. Two other new carbamate finishing agents, dimethylol methoxyethyl carbamate and dimethylol benzyl carbamate, have also been prepared in the research and used to produce wrinkle- and chlorine-resistant cotton. Present emphasis in the work is on deferred cure agents. (S2 1-230).

The experimental work in research studies of stretching and compressive shrinkage effects in ease-of-care fabric treatments has been completed by the contractor (North Carolina State of the University of North Carolina at Raleigh). Analyses of the data are in progress. Preliminary results indicate that smooth-drying properties of fabrics are not affected

appreciably by the stretching or compressive shrinkage in processes prior to curing. However, many other properties are affected by the mechanical processes, and it should be possible to utilize those mechanical processes which are advantageous in improving serviceability without affecting smooth-drying qualities of the fabrics. DMEU treatment was not as effective as either APO or DMEC (dimethylol ethyl carbamate) treatment in maintaining smooth drying properties of fabrics subjected to commercial launderings. (S2 1-183(C)).

Recent work has shown that high wrinkle resistance (wet or dry), essentially unchanged abrasion resistance, medium levels of wash-wear performance, lowered stiffness and unchanged tear strength are obtainable in all-cotton fabrics treated with crosslinked silicone films. The cellulose itself is not crosslinked. Dimethyl silicones of molecular weights 12,000-130,000 are cured with benzoyl peroxide on the fabric to give crosslinked films surrounding individual fibers. The efficiency of polymer insolubilization increases with increasing molecular weight. When the silicone treatment was applied to lustrous broadcloth woven of tension-mercerized yarn, the fabric gave a wash-wear rating of 4.0, retained considerable luster, had the same extraordinarily high tear strength as the untreated fabric, and its crease recovery was high (283° dry; 283° wet). After 5 launderings these values did not change, and the flex abrasion resistance of the fabric was 91% of that for laundered, untreated fabric. It has also been found that the silicone and benzoyl peroxide catalyst can be used to replace 50-66% of the cellulose crosslinking agent usually needed to impart a high level of wrinkle resistance. The formulation on slack mercerized cotton fabric gave a fairly high wash-wear rating (4.0), high tearing and breaking strength, and high flex abrasion resistance. Thus it may be possible to prepare wash-wear stretch fabrics of high abrasion resistance by using only enough cellulose crosslinking agent to prevent growth and permanent deformation on repeated flexing, and relying on the silicone and peroxide to impart easy-care properties. Delayed curing systems utilizing silicone finishes will be studied. This approach appears to have potential for avoiding the large losses of abrasion resistance common to delayed cure finishing. (S2 1-253).

2. Development of Optimum Wash-Wear Fabric Structures. Further analysis and summarization of data obtained in the research on relationships between fabric structure and ease-of-care performance of cotton fabrics has been carried out by the contractor (Fabric Research Laboratories). The research has shown that fabric structure effects are greater in heavier than lighter weight fabrics when the fabrics are treated to the recommended resin add-on to insure high wash-wear rating. Fabric structure is extremely important in smooth drying behaviors of scoured and mercerized fabrics. It was found that the more open weave fabrics and fabrics of long floats have distinct advantages in smooth drying and usually have higher tearing strength than the tight and square weave fabrics even after wash-wear treatments. Mercerization improves both smooth drying properties and tearing strength. The smooth drying properties of fabrics after tumble drying were more reliably estimated from crease recovery at 120°F., 15% R. H. than at standard

condition (70°F. 65% R.H.) or at any of several other combinations of moisture and temperature within this range. Temperature and humidity effects on flexural rigidity are very small. The resin treated mercerized fabrics generally decrease in stiffness while the scoured fabrics, especially with the tight weave, increase in stiffness with increase in humidity. Fabric stiffness is less important than crease recovery in achieving smooth drying. (S2 1-170(C)).

Cooperative research with the Cotton Producers Institute to develop optimal cotton fabric structures, for men's trousers and dress suits is in progress. DMEU-crosslinked, experimental fabric structures, formed into trouser cuffs and sleeves and in some instances crosslinked a second time to simulate delayed-cure conditions, were tested for wearability by repeatedly washing and tumble drying. Three popular weave types--twill, plain, and worsted (double cloth construction)--were studied. After 30 wash cycles, the simulated delayed-cure samples showed limited wear, but were superior to the other samples in smooth-drying properties and retention of creases. In the twills, those with a 63° twill angle outperformed those with a 45° twill angle. Based on these preliminary exploratory experiments, fourteen experimental fabric structures, including printcloth, gabardine and seersucker weaves, were prepared, treated with DMEU resin, and fabricated into trouser cuffs which were pressed and then cured in an oven. The cuffs were tested for wearability via repeated launderings using conventional and modified (extended) laundering procedures. Wear was found to be greatest when the tumble drying time was extended, and least when the washing time was extended. In another experiment, laundering tests (30 launderings) were carried out on similar test cuffs made from fabrics woven from slack mercerized stretched yarns, except that in this case a commercial delayed cure resin was used. Preliminary study of the results indicated that the fabrics woven from the premercerized yarns gave improved wearability.

Two hundred yards of one of the promising experimental fabrics (a gray-striped, summer-weight seersucker woven from similarly premercerized Pima S-2 cotton yarns) have been supplied to the National Cotton Council for commercial finishing, fabrication into suits, and service testing during the summer. The yarn premercerization procedure gives considerable promise of improving wearability of permanent press cotton garments. Test fabrics are currently being woven from commercial tension-mercerized yarns for use in studying the effect of yarn ply twist on fabric wearability. (S2 1-254).

C. New and Improved Processing Methods

1. Wash-Wear Cotton Stretch Goods With Improved Properties. The project to investigate finishing treatments for the production of wash-wear cotton stretch fabrics with improved strength, drape and hand has been terminated. The improved fabric strengths achieved by restretching slack mercerized samples have been further increased by inducing greater swelling by diluting the caustic in the impregnated fibers prior to restretching of the fabrics. Crystalline conversion to cellulose II is not extensive for slack mercerized

fabric and is even less after restretching. Therefore, better realignment of stress-bearing areas within the fibers rather than crystalline changes seems to be the mechanism whereby improved strength is achieved. Recent studies on fabrics having different yarn and fabric structures have shown that loss of breaking strength of fabrics which are slack mercerized, restretched, and then crosslinked may be reduced, depending on type of yarn used. Employing a two-ply yarn gives less strength loss, compared to the grey fabric, than when a singles yarn is used. In some cases essentially 100% of the breaking and tearing strengths of the grey fabric have been retained. Work along these lines is being continued under other projects directed toward producing wash-wear fabrics and garments with improved abrasion resistance. (S2 1-211).

Exploratory experiments have indicated that preferential crosslinking of cotton in selected regions of the fabric structure is a promising new approach for improving abrasion resistance of durably pressed, wash-wear cotton garments. Two techniques have been developed for crosslinking the back side of a fabric, leaving the front (wearing) side uncrosslinked for improved abrasion resistance: (1) direct back coating with a viscous solution of a crosslinking agent, and (2) use of a catalyst-inactivating reagent for face coating a fabric previously impregnated with a crosslinking agent but not cured. These procedures should lead to reduced processing costs since less crosslinking agent would be required. Also, resins which tend to cause yellowing of white goods could be employed since the discoloration would be on the back side only. Use of preferential crosslinking on slack mercerized, partially restretched fabrics shows particular promise for improving wear life. However, evaluation tests of trouser cuffs by home washing and tumble drying showed some wear on all samples, indicating that additional research will be needed to develop a satisfactory durable press treatment for 100% cotton garments. Polymer additions and surface reactions will be investigated to reduce fibrillation and dye fading at creases and seams of durably pressed garments.

2. Development of Improved Cotton Sewing Thread for Wash-Wear Cotton Products. Research is being conducted under contract at Georgia Tech Research Institute to develop improved cotton sewing thread for wash-wear fabric structures, compatible with existing high-speed manufacturing methods, which will not cause seam pucker or which will have a markedly reduced tendency to cause seam pucker. The contractor has obtained all fabrics and threads required for the research. Physical characteristics of these materials have been determined, and sewing tests have been initiated to evaluate the physics of seam pucker. Initial sewing tests will be on printcloth samples, to be followed later by the other types (oxford, broad-cloth, and gingham). A photoelectric procedure for objectively measuring seam pucker shows promise and its development will be continued. (S2 1-228(C)).

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COTTON PRODUCTS WITH SPECIAL PROPERTIES

Southern Utilization Research and Development Division, ARS

Problem. In many uses where special properties are of paramount importance, cotton is being replaced by synthetic materials. To improve its position in the textile market, which has declined from 79.5% of mill consumption of all textile fibers in 1939 to an estimated 55% in 1964, new applications must be explored and improved products developed to meet the competition of synthetic fibers. Cottons having high recoverable stretch, durable loft, light-weight bulk, pleasing textures, warmth and other highly desirable properties are needed to enable cotton to compete successfully with synthetic fibers in the rapidly expanding market for stretch and bulked type fabrics. Fabrics designed to achieve increased resistance to tearing and abrasion, flex life and other strength properties are needed to improve the wear life of cotton textiles for apparel, household and industrial uses. Cotton fabrics must be designed to withstand better the elements of weather and finishes developed that will provide greater protection from solar radiation, microorganisms, acids and fire, and that will resist color change. Additional basic information must be developed to improve cotton's resistance to water and oil-borne soils, and to dry soiling. Resistance to soiling ranks fifth in importance among the 40 end-use qualities for textiles. Cheaper and more durable flame retardant finishes for cotton, specially for outdoor use, are needed. Numerous consumer preference surveys have shown that a great potential demand exists for cotton material that will be more lustrous without sacrifice of functional properties. Cotton textiles with multipurpose finishes are also needed, particularly those where several desirable end-use properties can be introduced in a single process. Improved insect-resistant cotton bags for the storage and shipment of food commodities is another type of cotton product that must be developed.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, analytical chemists, physical chemists, physicists, microscopists, chemical engineers, cotton technologists, textile technologists, and textile engineers engaged in both basic and applied research to develop new or improved cotton products possessing special properties to meet the competition of synthetic fibers and other synthetic materials in various end uses. Informal cooperation is maintained with textile finishers, chemical manufacturers, and textile research institutes in connection with the research.

Research is carried out at New Orleans, Louisiana, in cooperation with the Foundation for Cotton Research and Education (affiliated with the National Cotton Council of America) and the Canvas Products Association International, to develop cotton fabrics with improved resistance to outdoor weathering. This research includes discovery of new and more effective biocides, and

sunlight-resistant pigments for cotton textiles; and development of improved formulations, equipment and procedures for producing weather resistant cotton textiles including those having durable color and water repellency in addition to weather resistance. Additional research is being conducted under contract at Texas Woman's University, Denton, Texas, on development of weather-resistant, water repellent finishes for cotton; and at Southern Research Institute, Birmingham, Alabama, on investigation of interfacial and graft polymerization procedures for producing weather-resistant cotton textiles with improved physical properties.

Research to develop new fluorochemical finishes for oil- and water-repellency and other reactive and additive finishes is conducted at New Orleans, Louisiana, to improve cotton's soil resistance. Additional research is being performed: (1) under contract at the Harris Research Laboratories, Inc., Washington, D. C., to provide fundamental information on the mechanism of the soiling of cotton by dry soils, and water-, oil- and solvent-borne soils, which could lead to the formulation of a general theory of the soiling of cotton and modified cotton; and (2) under a grant at the University of Arizona, Tucson, Arizona, on correlation of surface microtopography of treated and untreated cotton fibers with resistance to soiling of cotton textiles.

Research on flame-resistant cotton textiles is performed at New Orleans, Louisiana. Emphasis is on the development of durable inexpensive flame retardants for cotton, and treatments to impart flame resistance to cotton while at the same time imparting other desired textile properties.

Investigations of methods for imparting durable luster and related appearance characteristics to cotton textiles are carried out at New Orleans, Louisiana. Current research is concerned with the development of lustrous wash-wear fabrics with increased strength and durability.

Research to improve cotton's bulk, elasticity and resilience through resin treatment, chemical modification, slack mercerization and other type swelling treatments, of fibers, yarns and fabrics is conducted at New Orleans, Louisiana. The research on fibers is aimed primarily at the development, by chemical or mechanical means or both, of more resilient and cohesive cotton batts for use in mattresses and other padding applications in the furniture and automobile industries. The cotton batting research is conducted cooperatively with the National Cotton Batting Institute, Textile Waste Association, National Cottonseed Products Association and the Foundation for Cotton Research and Education (affiliated with the National Cotton Council of America). Work on yarns is intended to produce bulky, elastic yarns suitable for weaving or knitting into fabrics with improved stretch and bulk characteristics. Investigation of a slack mercerization process with and without subsequent resin treatment, is being carried out to achieve improved stretch cotton fabrics for industrial, household and apparel uses. The influence of yarn and fabric structures on the properties of the stretch fabrics is being studied. Additional research on stretch and bulked cotton

products is being carried out under contracts at North Carolina at the University of North Carolina at Raleigh, Raleigh, North Carolina, on evaluation of stretch-type cotton yarns (prepared by backtwisting and false-twisting techniques) in knit wear; and on determination of optimum yarn constructions, knitting structures and prefabrication design for producing stretchable articles of knitted cotton wearing apparel by slack mercerization; and at Clemson Agricultural College, Clemson, South Carolina, on development of cotton knit fabrics having increased bulk, warmth, and dimensional stability by application of finishing agents.

Research to develop improved insect-resistant cotton bags for the storage and shipment of food commodities was recently initiated at New Orleans, Louisiana. The Stored-Product Insects Research and Development Laboratory, Market Quality Research Division, ARS; bag manufacturers; and the Textile Bag Manufacturers Association cooperate in the work.

The Federal in-house scientific effort devoted to research in this area totals 25.9 professional man-years. Of this total, 6.0 is devoted to weather resistant cotton fabrics, 2.3 to soil resistant cotton textiles, 6.8 to flame resistant cotton textiles, 2.0 to cotton textiles with improved luster, 5.5 to stretch and bulked cotton products, and 3.3 to insect-resistant cotton bags. The domestic contract and grant research involves an additional 6.9 man-years, 1.5 being on weather resistant cotton fabrics, 2.3 on soil resistant cotton textiles, and 3.1 on stretch and bulked cotton products.

PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given under Area 1)

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Weather Resistant Cotton Fabrics

1. Improved Biocides, and Sunlight-Resistant Pigments for Cotton Textiles; and Improved Formulations, Equipment, and Procedures for Producing Outdoor Cotton Textiles. In cooperative research on weather resistant cotton fabrics with the Canvas Products Association International and the Foundation for Cotton Research and Education, studies of zirconyl acetate - and zirconyl ammonium carbonate - metal salt fungicides have continued. Cotton duck treated with one of these agents--copper zirconyl boroacetate--has completely resisted mildew and algae growth for more than 36 months of outdoor exposure. Five companies are currently using these new treatments for commercial production of outdoor weatherable cotton fabrics. Recent work has shown that copper salts solubilized with zirconyl acetate or zirconium ammonium carbonate can be effectively cured on cotton fabrics at 80°C, whereas optimum curing temperatures for phenylmercury derivatives vary between 80°C and 130°C depending on the particular derivative employed. Of particular practical importance is the fact that the phenylmercury

derivatives of zirconium which have been deposited on fabrics have much greater resistance to water leaching than the amine-phenylmercury agents now in use. Several new phenylmercury compounds have been prepared by a new method of synthesis, and found to have very good rot resistance as determined by soil burial tests. Combinations of several metals with zirconium have been found to give additive fungicidal effects but little evidence of synergism to date. Other metallic ion combinations are being investigated in attempts to discover synergistic combinations. (S2 1-259).

Other cooperative work is concerned with the development of multipurpose finishes for outdoor cotton fabrics. Cotton fabric samples treated with clear base finishes based on methylolmelamine and coated with pigmented vinyl resins have withstood one year of outdoor exposure without loss of strength. This performance should be of considerable interest to finishers of outdoor fabrics. It has been found that if methylated methylolmelamine is substituted for methylolmelamine, a considerable increase in useful storage life of the resin-zirconium acetate treating solution is obtained. Fabrics finished with methylated methylolmelamine are currently being evaluated for weather and rot resistance. A method has been devised for determining the reflection, absorption and transmission characteristics of treated and untreated outdoor cotton fabrics. The measurement of the sunlight ultraviolet optical characteristics of these fabrics, when compared with the fabrics' outdoor performance, may possibly afford some insight into the mechanisms of actinic degradation and/or protection. Studies of the role of atmospheric contamination in cotton fabric degradation at various continental United States sites are also in progress, in cooperation with the Air Pollution Division of the U. S. Department of Health, Education, and Welfare. (S2 1-256).

Based on completed initial phases of the contract research at Texas Woman's University to develop weather-resistant, water-repellent finishes for cotton, the best water repellents have been selected and are being tested in combination with four selected weather-resistant finishes. When exposure tests of the fabrics at various environmental sites are completed, much useful information concerning these types of finishes will become available. (S2 1-200(C)(Rev.)).

Contract research has been initiated at Southern Research Institute to investigate interfacial and graft polymerization procedures for producing weater-resistant cotton textiles with improved physical properties. The factors controlling the amount and uniformity of graft polymerization of acrylonitrile onto cotton printcloth have been studied in some detail and the evaluation of the grafted products has been started. The most uniformly grafted products were obtained by radiation initiation or by ferrous ion-initiation with the solution method of monomer application. The ceric ion-initiation method gave more rapid reactions than other methods investigated. A polymer add-on greater than 10% stiffened the fabric appreciably and, in some cases, the fabric structure was noticeably tightened by the treatment. Microscopic examination showed definite differences in the products obtained by the different grafting methods. This method of

finishing cotton has potential for imparting many new properties. (S2 1-245(C)).

B. Soil Resistant Cotton Textiles

1. Basic Studies of Soiling and Soil Removal. The contractor (Harris Research Laboratories, Inc.) has obtained additional fundamental information on the dry soiling and oily soiling properties of cotton fabrics, some of which were crosslinked with formaldehyde at two degrees of swelling, chemically modified to introduce cationic or anionic groups, and/or coated with various finishes having a range of hardness, thermoplasticity, charge, and hydrophobicity. The nature of the coating on the fabric was found to have the greatest effect on dry soiling and laundering. Hardness of the coating was found to influence soiling and soil removal even when the coating was applied to chemically modified fabrics. Generally, crosslinking with formaldehyde results in fabrics which retain more soil in laundering than the noncrosslinked cottons. Form D fabrics (crosslinked in the nonswollen state), especially when subsequently chemically modified, soil less with dry or oily soil and retain more soil during laundering than comparable Form W fabrics (crosslinked in the swollen state). Fabrics coated with acrylates, regardless of hardness, had only about half the soil removed when drycleaned. Soil redeposition in dry cleaning was especially heavy among finishes from which soil was difficult to remove. The basic findings will be useful in developing new soil resistant finishes for cotton. (S2 1-223(C)).

Research was recently initiated under a grant at the University of Arizona to determine the surface microstructure of untreated and of chemically finished cottons with relation to soil attraction and soil retention. A high-resolution electron microscope has been installed by the grantee for use in the research. Techniques for making replicas of the surface of cotton fibers are being perfected, preliminary to initiating studies of soiling. The research should lead to a better understanding of the soiling of cotton and point the way to improvements in soil resistance. (S2 1-238(Gr.)).

2. Development of Fluorochemical and Other Soil Resistant Finishes for Cotton. Research to develop durable water- and oil-repellent finishes for cotton fabrics through the use of fluorochemicals has continued. The 1,1-dihydroperfluoroamines, for which a high-yield method of synthesis was recently devised, have been shown to be useful in incorporating long-chain perfluoroalkyl groups onto cotton cellulose. These amines are not cellulose-reactive but can be attached via reaction with cellulose-reactive materials such as THPC, THPC-urea precondensates, and modified polyethylenes. The perfluoroalkyl groups render the fabric oil repellent and, depending on the material used to attach the fluorochemical to cotton, water repellency may also be improved. Experiments are in progress to attempt to increase water repellency and lower strength losses from these treatments. Due to the extreme instability of alpha-chloromethyl fluoro ethers, further research on the modification of cotton with these agents has been abandoned. (S2 1-250).

C. Flame Resistant Cotton Textiles

1. Treatments to Impart Flame Resistance and Improved Textile Properties to Cotton. To increase the acceptance of flameproofing finishes by industry, research is in progress to develop durable inexpensive finishes. Inexpensive organic and inorganic compounds were added to APO, APO-THPC, and THPC-urea flameproofing agents with a significant reduction of the amount of expensive phosphorus compound needed. Although some of these modified finishes rendered cotton fabrics flame resistant, some of the fabric properties, such as durability and strength, were not as good as desired. Nevertheless, this approach warrants further investigation. In other work, it was found that the efficiency of the previously developed THPC-urea-NH₃ flameproofing process is increased by raising the pH level of the precondensate with sodium hydroxide. Cotton stretch fabrics were made flame resistant by application of this and other standard finishes, at the same time improving recovery properties of the fabrics. Flame retardancy has also been imparted to cotton fabrics by application of formulations consisting of bromendic anhydride, urea, and THPC. THPC has also been reacted with selected nitrogen-containing compounds and with polyhydroxy compounds to form highly crosslinked flame-resistant polymers. Evaluations of these materials are continuing, with emphasis on developing nonyellowing, strength-retaining finishes.

Use has been made of differential thermal analyses (DTA) and thermogravimetric analyses (TGA) for studying the mechanism of flame resistance. DTA thermograms indicated differences in decomposition characteristics between phosphorus type flame-resistant finishes and halogen type finishes. All of the flame-resistant fabrics decomposed at considerably lower temperatures than untreated cotton. TGA thermograms of flame-resistant samples showed more rapid weight losses and larger residues than those of untreated cotton. When the fabrics were heated under oxygen rather than nitrogen, decomposition was more complete and residues were smaller. Utilization of basic findings from this work should be helpful in the development of improved flame-retardant finishes for cotton. (S2 1-257).

Investigations to impart multifunctional properties--including flame resistance, crease resistance, rot resistance, improved dyeability, etc.--to cotton in a single treatment are continuing. Two new organophosphorus compounds with cellulose reactive chlorohydrin groups were synthesized: bis(1-hydroxy 2-chloroisopropyl)phosphinic acid, and bis(1-hydroxy 2,2'-dichloroisopropyl)phosphinic acid. Also, a simple method of preparing bis(chloromethyl)phosphinic acid in good yield was discovered. These three compounds were found to crosslink cotton in the presence of sodium hydroxide to produce fabrics with good wet wrinkle recovery, increased moisture regain, ion-exchange properties, increased receptivity to basic dyes, and a degree of flame resistance. In another phase of work, it has been discovered that the strength of cotton fabric treated with the formic acid colloid of methylolmelamine can be significantly increased by partial acid hydrolysis of the finish, at the same time maintaining considerable rot resistance. Research will be carried out on the preparation of aminomethyl phosphinic

acids (and esters) from chloromethyl phosphinic acids and ammonia. These compounds will be used as intermediates in the production of polymers on cotton to impart multifunctional properties. (S2 1-251).

D. Cotton Textiles With Improved Luster

1. Processes for Imparting Durable Luster and Increased Strength and Durability to Wash-Wear Cotton Textiles. Research is in progress to develop lustrous wash-wear fabrics with increased strength and durability. Various methods of yarn mercerization were investigated. Two-ply yarns of several varieties of cotton, both rain-grown and irrigated, mercerized at normal length (NL), to 3% above NL, or slack and restretched showed no loss in breaking strength after crosslinking with DMEU, when compared to the uncrosslinked grey controls. Most of the yarns mercerized slack and restretched to NL or to 3% above NL showed a gain in breaking strength of 27-45% after crosslinking. The loss in breaking strength of these crosslinked mercerized yarns ranged mostly from 0-10% when compared to the uncrosslinked mercerized controls. By these methods, it would be possible to obtain a wash-wear fabric with considerable elongation as well as high strength retention. A wash-wear fabric with luster and high strength retention could also be made if mercerization is carried out using considerable tension. In the next phase of the research, 60/2 combed grey yarn will be mercerized by different methods, and woven into broadcloth fabrics for crosslinking. (S2 1-267).

E. Stretch and Bulked Cotton Products

1. New and Improved Processes for Production of Stretchable Cotton Yarns and Fabrics Using Chemical and Mechanical Treatments. Experiments to determine the effect of fabric structure and aftertreatments on the properties of both filling-stretch and two-way stretch cotton fabrics woven from stretch yarns produced by crimping resin-treated yarns using the back-twist method have been successfully completed. Fabrics with up to about 90% stretch were produced. It was found that fabric stretch could be adequately controlled by adjusting the thread count, and was also dependent upon the type of weave. Sateen and other weaves with long floats produced fabrics with the most stretch. In general, abrasion resistance improved as the amount of stretch was increased. The dimensional stability, wrinkle resistance, and recovery properties of the stretch fabrics were significantly improved by aftertreatment with a resin to a level of add-on of 3 to 4%. Strengths of the fabrics decreased 5 to 30%, compared to the untreated stretch fabrics. The flat abrasion resistance of the aftertreated fabrics was slightly less than that of the untreated stretch fabrics, but equal to that of untreated, nonstretch fabrics of comparable structures. Fabrics woven from the stretch-type cotton yarns were also aftertreated using a deferred curing procedure to impart permanent creases. Trouser cuffs made from these fabrics exhibited excellent wrinkle resistance, crease retention and wearing qualities after 30 home launderings. The stretch yarns and fabrics developed under this terminated project have created considerable interest in the textile industry and commercialization is anticipated. One textile machinery

manufacturer is in the process of developing high speed falsetwisting equipment for producing cotton stretch yarns commercially. (S2 1-193(Rev.)).

Fabrics with a high degree of easy filling stretch have also been woven from cotton stretch yarns prepared by other combinations of chemical and mechanical treatments, such as acetylation, cyanoethylation, grafting with acrylonitrile, and mercerization, followed in each case by backtwisting. Falsetwisting techniques also proved applicable in conjunction with acetylation or cyanoethylation. The recovery of the various fabrics from stretching was very good; however, due to the large amount of stretch obtained, the percent growth was higher than desired. High and normal twist cotton yarns mercerized under tension and slack, at room and elevated temperatures and in the presence of sodium thiocyanate, and subsequently backtwisted, showed some stretch properties which were carried over into fabric woven from these yarns. (S2 1-213).

In research to develop cotton knit fabrics having increased bulk, warmth, and dimensional stability by application of finishing agents, the contractor (Clemson Agricultural College) has found that improved bulk is dependent not only on technique of application of an agent but also on the type agent used. Vacuum-centrifuge application of tris(1-aziridinyl)phosphine oxide (APO) and dimethylol ethyleneurea (DMEU) has given best overall appearance and dimensional stability of cotton wash-wear knit goods having increased bulk. Results of laundering tests suggest that dimensional stability is being achieved with little change in volume of the fabric. Greater bulking of the fabric is still needed to achieve significantly increased warmth properties to make the process attractive commercially. Improved bulking treatments will be sought through use of tumble drying and curing apparatus, and swelling treatments before and during crosslinking. (S2 1-205(C)).

The contractor (North Carolina State of the University of North Carolina at Raleigh) has now established satisfactory knitting techniques and fabric structures for the production of knit fabrics from 24/2 and 60/2 stretch-type cotton yarns made by the false-twist method, as was previously done for the back-twist method. All of the crew socks and T-shirts required for service testing have been knitted from the stretch yarns produced by the two methods. Preliminary service tests on the garments are now in progress to guide the design of the large service tests scheduled for initiation in September 1965. Information being developed in the research should furnish the industry a sound basis for designing, producing and promoting such stretch fabrics and garments. (S2 1-197(C)(Rev.)).

2. New and Improved Processes for Production of Stretchable Cotton Textiles Using Slack Mercerization and Other Type Swelling Treatments. Further research has been conducted to develop cotton fabrics with improved warp and filling stretch properties by slack mercerization. Experiments on variations in yarn structure of plain and twill weave fabrics have shown that slack mercerization for 1-way stretch produces fabrics with similar stretch properties when low-twist filling yarns are used, regardless of yarn size.

When high-twist filling yarns are used, smaller filling yarns produce fabrics with a greater amount of easy stretch and consequently more growth than those made with larger filling yarns. Both 1-way and 2-way stretch fabrics woven with high-twist filling yarns had more filling stretch and greater growth than those woven from low-twist filling yarns. One-way stretch fabrics had greater easy filling stretch and better recovery than 2-way stretch fabrics. The relative size of the warp and filling yarns had an important influence on the stretch properties of 2-way stretch fabrics, more easy stretch usually being produced in the direction in which the smaller yarns were running. One-way stretch plain weave fabrics had significantly improved warp strength properties after resin treatment if mercerized under warp tension. Fabrics with two-ply warp yarns gained as much as 25% in warp breaking strength and those with singles warp yarns lost less than 20% in warp breaking strength in comparison with their untreated control fabrics. Filling breaking strength losses of stretch fabrics made from either plied or singles yarns were about the same as compared with their controls. The recovery of stretch fabrics woven from plied yarns was greater than that of stretch fabrics woven from singles yarns. Flex endurance in both warp and filling directions was increased by increasing the number of warp ends per inch which also reduced filling growth after cyclic loading tests.

Pretreatment of filling yarns by either scouring, slack mercerizing, or mercerizing at normal length did not give any improvement in the properties of the slack mercerized, finished fabrics. The combination of base-catalyzed crosslinking and slack mercerization resulted in all-cotton stretch yarns with improved wet recovery after stretching; and fabrics woven from the yarns had improved wet recovery after stretching, and better wet wrinkle recovery. (S21-213, S2 1-226).

Contract research on the production of stretchable knitted cotton wearing apparel by slack mercerization is in progress at North Carolina State of the University of North Carolina at Raleigh. Experiments in which shrinkages of yarn in slack mercerized skeins and shrinkages of yarn in knittings were compared have indicated that knitting structures offer restraint to yarn shrinkages even in very loose fabrics. Evidence of correlation between shrinkage of yarn and of loosely-knitted fabric has been obtained. Studies on the skewness of loosely knitted fabrics showed that fabric length was proportional to the angle of skewness which increases with the twist in the yarn being knitted. Preliminary study of slack mercerized yarns showed that: yarn shrinkage was proportional to yarn twist and was not influenced much by yarn count; 10% caustic solution was not sufficient for mercerization when other conditions were normal; yarn shrinkage was reduced at higher caustic temperatures but was not influenced appreciably by wash-water temperatures when 20% caustic was used for mercerization. Loosely-knitted socks will be made, slack mercerized, and evaluated. (S2 1-224(C)).

At least 30 companies are now producing all-cotton stretch fabrics by the slack mercerization process. All-cotton stretch men's hose are also being produced commercially, both by slack mercerizing loosely knit hose and by knitting hose from slack mercerized stretch yarns. This rapid advance in

commercialization of stretch cottons has been achieved to a large degree because of active coordinated research between the Southern Division and commercial weavers, finishers and knitters. Active cooperation is continuing with several companies who are doing development work on stretch fabrics, stretch laces, stretch socks, and the molding of stretch fabrics.

3. Resilient and Cohesive Cotton Batts from Low Cost Cotton. Investigations to improve the production and the performance characteristics of chemically treated cotton batting have continued in cooperation with the National Cotton Batting Institute, the Textile Waste Association, the National Cottonseed Products Association, and the Foundation for Cotton Research and Education. More definitive information on the drying mechanism was obtained through the establishment of the effects of relative humidity, temperature, time, air velocity, static pressure, and pressure differential through the in-process product. Many new resins and latexes, some especially compounded by the chemical companies for application to cotton batting, were evaluated for efficacy in improving the performance of the product. Alternative methods of chemical treatment, including treatment of rawstock, were explored. Also, fiber randomization within the array was further evaluated. Present emphasis in the research is on commercialization aspects. Two major automobile manufacturers have approved the new chemically treated batting--"Cotton Flote"--for use in some of their 1965 models; and one producer of batting has already manufactured and supplied large quantities of Cotton Flote for this purpose. It is anticipated that another major auto manufacturer will approve the product soon. At least seven other batting producers are piloting the process for making Cotton Flote. As the availability of the new product increases, its use will undoubtedly be extended to the bedding and furniture manufacturing industries. (S2 1-181(Rev.), S2 1-269).

F. Insect-Resistant Cotton Bags

1. Development of Improved Insect-Resistant Cotton Bags. Research to develop improved insect-resistant cotton bags for the storage and shipment of food commodities was recently initiated in cooperation with the Stored-Product Insects Research and Development Laboratory at Savannah, Georgia, bag manufacturers, and the Textile Bag Manufacturers Association. Initial work has shown that inexpensive coatings based on wax, or starch (with talc as a filler), can be used effectively to seal commodity bag fabrics. Also, calendering of insecticide-treated fabrics appears extremely promising for this purpose. A number of fabric samples, with and without varying levels of insect repellent treatment, are currently undergoing evaluation at the Savannah laboratory. (S2 1-271).

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COTTONSEED PROCESSING AND PRODUCTS

Southern Utilization Research and Development Division, ARS

Problem. Cottonseed products, currently approximately two billion pounds of oil and 2.8 million tons of meal derived from the annual domestic production of cottonseed, face increasing competition for markets. For its chief market, edible products, cottonseed oil must compete with other vegetable oils and animal fats. The nation's capacity for producing these oils and fats is so great that supplies can be expected to exceed both domestic and foreign demand for some time to come. Improvements in the quality and utility of cottonseed oil are needed to retain present and open new markets for the currently large and possibly greater future production. Cottonseed meal, used chiefly as a protein supplement in feeding ruminant animals, faces serious competition from synthetic urea and other supplements. The quality and nutritive value of the meal must be improved and new outlets developed.

Much research is urgently needed on the fungi and toxic fungal metabolites which may develop in cottonseed and its processed products. The mycotoxin problem is a potentially serious one for many agricultural commodities. Also, additional information is urgently needed on the chemical, physical, and biochemical properties of cyclopropene fatty acids in cottonseed and means of converting them, if found necessary, into physiologically inert forms. Usually there is discrimination in the markets against 25% to 50% of the production of cottonseed oil due to the presence of reddish colors that are not removed by conventional commercial refining, bleaching and deodorizing methods. It is essential that information be developed on the chemistry of the pigments responsible for the off-colors, and that more efficient means be developed to eliminate them and thus upgrade the oils, particularly for use in margarine and shortening. New types of modified fats, such as polyester and polymeric fats, need to be developed from cottonseed oil for applications in the fields of edible and inedible coatings, waxes, resins, plasticizers, and lubricants. Improved cocoa butter-like fats and other confectionery fats derived from cottonseed oil could also provide new markets for large quantities of oil. Fundamental information is needed on hydrogenation to permit production of improved modified fats and oils. Other areas in which markets for cottonseed oil need to be developed through research include fat emulsions for intravenous feeding, edible emulsifiers, and fatty acid amides and other derivatives for use in various industrial products. Improvement in the quality and nutritive value of cottonseed meal is needed so that it can better compete with other protein feed supplements. Additional information is needed on the physiologically active constituents of the meal responsible for egg abnormalities, swine mortalities and growth abnormalities of young animals that limit cottonseed meal's usefulness in poultry and swine rations, and for the reported implication of cottonseed meal in the incidence of trout hepatoma which has resulted in its elimination from use in fish feeds in certain areas. Processing methods must be devised for the commercial

production of meals that can be fed to broilers, laying hens and swine, safely and without restriction. Procedures for the preparation of cottonseed flours and their derived products for human consumption in developing countries also must be developed. In order to lay the necessary groundwork for further advances in cottonseed research on food, feed and industrial products and processing technology, additional fundamental information is also needed on the chemical composition and properties of cottonseed and of various cottonseed products.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, physical chemists, analytical chemists, biochemists, chemical engineers, physicists, and microbiologists engaged in both basic and applied studies on cottonseed and its products to develop new or extended uses for these materials.

Research to develop fundamental information on the chemical composition and properties of cottonseed products is conducted at New Orleans, Louisiana, as a basis for efficient applied research in the fields of food, feed, and industrial products from cottonseed. Some important phases of current work involve research on the chemical, physical, and biochemical properties of cyclopropene fatty acids and other cottonseed constituents; and on fungi and toxic fungal metabolites which may develop in cottonseed and its processed products. The Foundation for Cotton Research and Education contributes towards research on the isolation and characterization of cyclopropene ring fatty acids of cottonseed. The National Cottonseed Products Association supports a Postdoctoral Research Associateship for conducting pioneering research on cottonseed proteins and biochemistry as a part of the Seed Protein Pioneering Research Laboratory's research. Additional research on chemical composition and physical properties is carried out: (1) under contract at the University of Tennessee, Knoxville, Tennessee, on investigations of gossypol esters and mild oxidation products of gossypol and gossypol derivatives; and at Purdue Research Foundation, Lafayette, Indiana, on fundamental investigations of chemical transformations of olefinic compounds of fats and other agricultural materials by hydroboration and subsequent reactions to develop basic information for the production of useful products; and (2) under a grant at Boston University, Boston, Massachusetts, on the development of procedures for synthesizing C^{14} -labeled malvalic acid esters.

New and improved food products and processing technology are developed in research conducted at New Orleans, Louisiana. In oil research, methods are being sought to produce improved cottonseed oils, and confectionery fats, polyester products, and fat emulsions for intravenous nutrition from cottonseed oil. The research on confectionery fats is cooperative with the National Confectioners' Association who maintain a Fellowship at the Southern Regional Research Laboratory, New Orleans, Louisiana, in partial support of the work, and evaluate promising research products. The Office

of the Surgeon General supports the research on fat emulsions. This research is conducted cooperatively with the U. S. Army Medical Research and Nutrition Laboratory and several medical school research groups. Other current work -- supported by the Agency for International Development -- involves a study of the preparation of cottonseed flours and their derived products for human consumption in developing countries. UNICEF cooperates by arranging nutritional evaluations of experimental products in developing countries, and the Human Nutrition Research Division, ARS, also cooperates by evaluating certain of the products. Informal cooperation is also maintained with industry in connection with the research on new and improved food products and processing technology. Additional research on new and improved food products and processing technology is conducted under contract at the University of Illinois, Urbana, Illinois, on chemical investigations of cyclopropenoids to develop practical means of eliminating or physiologically inactivating the cyclopropenoid constituents of cottonseed oil.

Research is carried out at New Orleans, Louisiana, to develop new and improved feed products and processing technology for cottonseed. Investigations are in progress to isolate and identify the physiologically active constituents in cottonseed meals that adversely affect the utilization of the meal as a protein supplement in nonruminant feeding; to isolate and chemically characterize the constituents of the protein systems of cottonseed to provide a basis for the further improvement of nutritive value of cottonseed meal; and to determine processing conditions for the production of cottonseed meals of maximum quality -- meals more suitable for feeding to nonruminants such as swine and poultry, as well as to ruminant animals. An important, recently initiated line of work is concerned with the development of economically feasible methods for the inactivation or removal of aflatoxins from contaminated cottonseed and cottonseed products to permit their utilization in feeds (and foods). Animal tests in connection with the overall research program are conducted through the cooperation of nutritionists in State Agricultural Experiment Stations at universities, in the Animal Husbandry Research Division, and in industry. The Pharmacology Laboratory at the Western Regional Research Laboratory, Albany, California, cooperates by conducting animal studies to determine the physiological and pharmacological effects of cyclopropene acids and toxic fungal metabolites. Cooperation is also maintained with the Crops Research Division, ARS, Market Quality Research Division, ARS, the Food and Drug Administration, the National Cottonseed Products Association, UNICEF, and members of the cottonseed industry. Additional research in the field of new and improved feed products and processing technology is in progress under contract at IIT Research Institute, Chicago, Illinois, on development of practical processing methods for inactivation of cyclopropene groups in cottonseed meal that decrease its value as a feed for laying hens.

Research to develop new and improved industrial products and processing technology is conducted at New Orleans, Louisiana. Present emphasis is on amide derivatives of long-chain fatty acids. Informal cooperation is maintained with industrial firms for the evaluation of promising research

products for specific end uses. Additional research on new and improved industrial products is being carried out under contract at the University of Arizona, Tucson, Arizona, on the polymerization of reactive chemical intermediates derived from cottonseed oil and other agricultural materials to produce polymers having potential industrial utility; and at U. S. Industrial Chemicals Co., Tuscola, Illinois, on copolymerization of ethylene with unsaturated fatty acids and other selected derivatives of agricultural materials to extend their utilization in commercial plastics.

Other research on chemical composition and physical properties is in progress under grants of P.L. 480 funds to the following foreign institutions: British Food Manufacturing Industries Research Association, Leatherhead, Surrey, England, for fundamental studies of the fatty acid and glyceride composition of cottonseed oil and the crystallizing behavior of some of the major components (project duration - 4 years); University of Bombay, Bombay, India, for a study of the relationship of substituent fatty acid groups on the physical properties of diacid triglycerides of palmitic and stearic acids as a means of increasing the utilization of cottonseed oil for food and industrial purposes (project duration - 5 years); Israel Institute of Technology, Haifa, Israel, for investigation of π -complexed organometallic compounds derived from polyunsaturated fatty acids to obtain fundamental information needed in expanding the utilization of cottonseed oil (project duration - 5 years); University of Rome, Rome, Italy, for basic investigations on the physical and physicochemical properties of cottonseed proteins (project duration - 5 years); and Commonwealth Scientific and Industrial Research Organization, Ryde, Australia, for an investigation of the chemistry and biological effects of cyclopropenoid compounds that occur in cottonseed and its products (project duration - 5 years).

Additional research in the field of new and improved feed products and processing technology is in progress under grants of P.L. 480 funds to the following foreign institutions: Instituto Farmacologico "Mario Negri", Milan, Italy, for a study of the mechanism of gossypol toxicity counteraction by L-lysine (project duration - 5 years); and Regional Cooperative for the Protection, the Development and the Practice of Fishing in Valle d'Aosta, Valle d'Aosta, Aosta, Italy, for experimental studies to elucidate the role of cottonseed meal in the induction of hepatoma in rainbow trout to obtain fundamental information concerning the suitability of cottonseed meal for use in rations for this species (project duration - 3 years).

Additional research to develop new and improved industrial products and processing technology is in progress under grants of P.L. 480 funds to the following foreign institutions: University of Montevideo, Montevideo, Uruguay, for research on the preparation, characterization, and evaluation of derivatives of gossypol for use as biologically active materials, ultraviolet absorbers, and other products (project duration - 5 years); Indian Institute of Science, Bangalore, India, for studies of the addition of carbenes to unsaturated fatty materials derived from cottonseed oil to

provide possible new outlets for utilization of the oil (project duration - 5 years); National Chemical Laboratory, Poona, India, for investigation of the synthesis and properties of new-type glycol mono alkyl ethers for control of water evaporation to extend the industrial utilization of cottonseed oil (project duration - 5 years); The Hebrew University of Jerusalem, Jerusalem, Israel, for a study of the preparation of new chemical derivatives from acrylonitrile and unsaturated fatty acids derived from cottonseed oil and other vegetable oils (project duration - 4 years); and the Hebrew University Faculty of Science, Jerusalem, Israel, for an investigation of metalation reactions for the modification of mono- and dienoic fatty acids to provide increased functionality, thereby leading to possible new industrial applications for cottonseed and other vegetable oils (project duration - 5 years).

The Federal in-house scientific effort devoted to research in this area totals 49.7 professional man-years. Of this number 22.3 is devoted to chemical composition and physical properties, 14.2 to new and improved food products and processing technology, 10.4 to new and improved feed products and processing technology, and 2.8 to new and improved industrial products and processing technology. The domestic contract and grant research involves an additional 7.5 man-years, 3.0 being on chemical composition and physical properties, 0.9 on new and improved food products and processing technology, 1.9 on new and improved feed products and processing technology, and 1.7 on new and improved industrial products and processing technology. P.L. 480 research involves 12 grants, of which 5 are on chemical composition and physical properties, 2 on new and improved feed products and processing technology, and 5 on new and improved industrial products and processing technology.

PROGRAM OF STATE EXPERIMENT STATIONS

Station research on cottonseed utilization is directed mainly toward increased feed use of the oilseed proteins. Efforts to increase the wholesomeness of cottonseed meal is centered on aspects of the gossypol and cyclopropenoid problems related in part to toxicity and in part to nutritional adequacy. When protein quality is poor, usually the lysine in the protein has combined chemically with sugars, fatty materials, or, in the case of cottonseed, with gossypol. Studies are in progress designed to determine the extent to which lysine, or possibly arginine or glutamine, has reacted. The investigations are aimed to better understand the reactions which interfere with proper utilization. High quality proteins in the rations of swine and poultry decrease costs.

Experiments designed to elucidate the effects of proteolytic enzyme action on gossypol-protein complexes have revealed purified, stable peptide end products which contain gossypol bound through lysine. Laboratory syntheses of cyclopropenoids and polymerization of sterculic acid have been examined. Methods of destroying the cyclopropene ring are being investigated. Studies on the structure of the cottonseed pigment gossyverdurin are proceeding.

Other studies include work on developing suitable methods and techniques for handling chemical residues of harvest aids in cottonseed.

The quality of cottonseed is affected by some mechanical damage during ginning, and the feasibility of storing seeds from one planting season to the next in normal warehouses is being related to viability and vigor. Changes in the composition of fatty acids resulting from the reuse of cottonseed oils for deep fat frying is being investigated. Additional studies on the roughage value of cottonseed hulls in dairy cattle feeds are being examined as a partial substitute for alfalfa hay.

The total research on the utilization of cottonseed products amounts to approximately 3.9 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Chemical, Physical, and Biological Properties and Structural Factors of the Proteins. The composition, properties, structural factors and reactions of oilseed proteins and associated materials are being investigated in a program of pioneering research conducted by the Seed Protein Pioneering Research Laboratory. The fundamental information developed should lead to new concepts and possibly new applications for oilseed proteins, including cottonseed protein. Since peanuts were found to be an especially suitable experimental material and employed for much of the early pioneering research on seed proteins, the report of progress in the research is given in Area No. 7, "Peanuts Processing and Products," as in the previous report.

A fundamental investigation of the physical and physicochemical properties of pure isolated cottonseed proteins is being conducted under a P.L. 480 project at the Institute of Biological Chemistry, University of Rome, Italy. A monodisperse major protein component has been isolated from the protein extracted from a glandless variety of cottonseed. This protein, called Acalin A by the investigators, has been characterized through amino acid analysis employing different methods of hydrolysis, end group analysis, dissociation into subunits of lower molecular weight, and solubility under different conditions. A second major protein which appears to differ from Acalin A has also been isolated from a glandless cottonseed extract, and has been purified to about 90% homogeneity in the ultracentrifuge. This component is currently under investigation. Some of the enzyme systems, including a transaminase, a glutamic dehydrogenase and a proteolytic enzyme, have also been isolated and studied. Such information is needed in the potential application of cottonseed proteins to human food needs (UR-315-(40)-33).

2. Chemical and Physical Properties of Cottonseed Pigments. In the contract research at the University of Tennessee on gossypol esters and mild oxidation products of gossypol and its derivatives, mild oxidation of tetramethylgossypol diacetate with chromic acid in acetic acid was found to

yield a new binaphthaquinone in 25% yield. Reactions of the binaphthaquinone will be investigated. The structure of the binaphthaquinone obtained when gossypol is oxidized with ferric chloride was also established. This quinone was converted to its tetraacetate, and the NMR and IR data obtained support the proposed structure. Anil derivatives of this quinone and its tetraacetate were obtained and characterized. The reaction which occurs when gossypol is dissolved in ethyl alcohol was also established in recent work. This basic research offers promise of applications to improve the color of cottonseed oil and the quality of meal, and should be of value in studies of the physiological effects of gossypol in animals ingesting cottonseed products. Future plans include investigation of the oxidation of gossypol under mild, nonalkaline conditions. (S4 1-103(C)).

3. Chemical, Physical, and Biochemical Properties of the Oil and Fatty Acids, Including Cyclopropene Fatty Acids. Excellent progress has been made in several lines of in-house research on the physiologically active fatty acids, called cyclopropenes, which are present in cottonseed oil and are believed to be responsible for various abnormal effects in animals fed rations containing cottonseed products. These investigations are continuing.

Several reliable, sensitive methods of analysis by which the presence of these unique fatty acids can be determined quantitatively in various types of cottonseed oils and concentrates have been developed. For the first time, accurate analysis can now be made of concentrates even in the presence of large amounts of interfering substances. A semimicro method, adapted from the previously developed macro hydrogen bromide titration procedure, has been developed to determine cyclopropenes in cottonseed oils. A method was also developed for the quantitative determination and isolation (as methyl esters) of the residual lipids in cottonseed meals, the first phase in the development of an analytical method for cyclopropenes in such meals.

Progress has been made on the isolation and concentration of the cyclopropene acids from commercial cottonseed oils, so as to determine exactly what types are present and to enable a study of possible physiological effects. Evidence has been obtained that malvalic and sterculic acids are the only cyclopropenes in the oil; they appear to be present in an 88:12 ratio. A systematic investigation of the concentration of cyclopropenes in the methyl esters of cottonseed fatty acids by fractional crystallization was conducted. For all the cyclopropenes to appear in the filtrate fraction, esters containing 0.66% cyclopropenes could not be crystallized from a 10% solution in methanol below about -60°C . Crystallization at -60°C . yielded fractions containing about 8% cyclopropenes. In the further concentration of the methyl ester fractions, countercurrent liquid-liquid fractionation appeared to be most suitable: relatively simple fractionations yielded concentrations containing as much as 64.5% cyclopropenes. Methyl sterculate derived from Sterculia foetida oil yielded fractions containing up to 90% methyl sterculate. Feasibility of employing this process on a larger scale will be investigated.

Several effective treatments for removing or inactivating cyclopropenes in cottonseed oil were developed in recent work -- in particular, treatment with monofunctional fatty acids has aroused considerable industrial interest. Six oils were treated with acids (acetic, capric, citric, oxalic, phosphoric, and mixed cottonseed fatty acids), another was partially hydrogenated, and still another was treated with $\text{SO}_2\text{-Al}_2\text{O}_3$; all treatments were effective in eliminating the major adverse effects on eggs produced by hens that had ingested normal cottonseed oil. The process of inactivating cyclopropenoids in cottonseed oil by simple heat treatment during the deodorization with monobasic acids, such as mixed cottonseed fatty acids, could be an important step in solving the cyclopropene problem, but additional research is needed.

In other research, efforts are being made to employ the organism, Tetrahymena pyriformis, as a reagent in determining if cyclopropene acids have an influence on the basic cellular metabolism of fat. Techniques for extraction of fat and determination of the fatty acid patterns of Tetrahymena pyriformis fat have been developed. (S4 1-105).

The contractor (University of Illinois) has conducted further research on the chemical and physical properties of cyclopropene fatty acids. Trans-2-phenylcyclopropyl trimethylammonium iodide reacted with potassium amide in liquid ammonia to yield a mixture which apparently contained 1- and 3-phenyl-cyclopropenes. 1-Phenylcyclopropene-3-carboxylic acid was prepared; it gave no Halphen reaction. Methyl stercolate was prepared by transesterification of Sterculia foetida seed oil by urea clathration and low temperature crystallization. Evidence has been obtained that methyl stercolate apparently undergoes rearrangement on storage to yield mixtures of two products. Data indicate that the most probable composition of the seed oil of Sterculia foetida is: palmitic, 2%; palmitoleic, 0.4%; stearic, 1.6%; oleic, 11%; linoleic, 11%; stercolic plus malvalic, 54%. Information developed under this contract has contributed to the development of methods for determination of cyclopropenes, the recognition and determination of the products obtained when cyclopropenes are chemically modified, and the recognition of reactions of cyclopropenes of potential physiological significance. (S4 1-104(C)).

Some exploratory investigations of the effects of gas chromatographic separation on the chemical composition of fatty materials have been carried out. Based on preliminary experiments with a sample of methyl stercolate of supposedly high purity, it appears that thermal conversion products of methyl esters of cyclopropene acids are formed during gas-liquid chromatographic analysis and the cyclopropene groups are destroyed. This points to the need for further information on the behavior of fatty materials when they are subjected to elevated column temperatures in gas chromatography.

In a P.L. 480 research project now getting well underway at the Division of Food Preservation, Commonwealth Scientific and Industrial Research Organization, Ryde, New South Wales, Australia, a study is being made of the chemistry and biological effects of cyclopropenoid fatty acids that occur in cottonseed and cottonseed products. These fatty acids, malvalic and

sterculic, occur in the seeds of many plants of the Malvalic order and are known to cause adverse physiological responses when fed to several animal species. Substantial progress has been made in isolating and purifying the cyclopropene containing fatty acids from natural sources, and in labeling them with radioactive carbon by biosynthesis. Information obtained through the use of these materials in chemical and biological tests will be of value in the extensive domestic research program to assess the significance of cyclopropenoids in food and feed uses of cottonseed production. (UR-01-(40)-2).

Basic investigations of methods for correlating and predicting solubilities of homologous and analogous long-chain saturated and unsaturated fatty acid derivatives are in progress. The pure cyclohexylamine salt of tridecanoic acid was prepared, and accurate solubility curves for the salt in methanol, benzene, and acetone were obtained. As the corresponding data for the cyclohexylamine salt of heptadecanoic acid and of the even C_{10} - C_{18} fatty acids were already available, it was possible to construct isopleth plots and predict the data for the solubility of the cyclohexylamine salts of undecanoic, pentadecanoic, and nonadecanoic acids in all three of these solvents. The experimental and predicted solubility data obtained are of fundamental importance in connection with the cyclohexylamine salt method for preparing pure fatty acids free from homologs.

Highly pure stearic, petroselinic, petroselaiddic, erucic, and brassidic acids have been prepared for use in this research. The accurate solubility data obtained for stearic acid in toluene overlap and agree very well with published solubility data for low temperatures. This curve of the combined data will be used as a basis for obtaining complete solubility curves for the large number of fatty acids for which data have been published on the low temperature solubility in this solvent. Solubility curves have also been obtained for stearic and myristic acids in N,N-dimethylformamide. These data will be used in obtaining, by prediction, solubility curves (1) for other members of the homologous series in this solvent by the isotherm and isopleth methods and (2) for related acids which are not homologs, by the new correlation procedure. Solubility data for a second, higher melting, polymorphic form of stearic acid has been obtained in toluene and N,N-dimethylformamide. The crystal structure of the new polymorphic form of elaidic acid was further characterized by X-ray diffraction measurements. Plans include the preparation of additional highly purified fatty acids for which the solubility in new selected solvents and solvent mixtures will be obtained. Theoretical analysis of existing and new data will be continued in an attempt to correlate solubility with other physical properties. These experimental and predicted solubility data, aside from their scientific value, are of fundamental importance in establishing the validity and scope of the new correlation procedure. (S4 1-129).

Additional fundamental information on the chemical transformation of olefinic compounds of fats by hydroboration and subsequent reactions has been developed in contract research at Purdue Research Foundation. In a systematic study of the hydroboration of terminal olefinic compounds containing various functional groups, such as hydroxy, alkoxy, phenoxy, acyloxy, carboalkoxy, and cyano, it was found that the alkoxy and phenoxy groups do not react with the diborane during the hydroboration of the olefinic moiety. Although the acyloxy, carboalkoxy and cyano groups react with diborane, these undesirable side reactions can be reduced or eliminated by adding only the theoretical amount of diborane to short-chain or relatively long-chain substituted olefinic compounds, such as ethyl and methyl 3-butenates, ethyl 4-pentenoate, t-butyl 3-butenate, 10-undecenyl acetate, methyl 10-undecenoate and 10-undecenitrile. The hydroxy group of olefinic hydroxy compounds, however, reacts preferentially to the olefinic moiety. The various organoboranes were easily oxidized to the respective hydroxy compounds by alkaline hydrogen peroxide; however, attempts to couple the organoboranes were not too successful. Since the carboalkoxyboranates could not be coupled, sterically hindered 5-butylacyloxyboranes have been synthesized to ascertain if unhindered alkylacyloxyboranes interfere with the coupling reaction.

In the hydroboration of terminal olefinic compounds containing various functional groups, disiamylborane (di-s-isoamylborane) has been found to exert more directive influence than diborane. That is, the electrophilic attack of the disiamylborane occurs almost exclusively at the terminal carbon of the olefinic moiety, whereas the diborane is less discriminating. The inductive effects of the various functional groups do not appear to be strong enough to affect the large steric requirement of disiamylborane. (S4 1-112(C)).

In P.L. 480 research at the British Food Manufacturing Industries Research Association, under a project now reaching its final phases, an investigation has been conducted on the fatty acid and glyceride composition of cottonseed oil and the crystallizing behavior of some of the major components. The fatty acid composition of a number of oils from cottonseed of various origins and processing histories have been examined by several different methods. Gas-liquid chromatography yielded results nearest to the accepted true values. Fractionation by low temperature crystallization has indicated that, although cottonseed oil contains 3 major component fatty acids, only 4 out of 26 probable triglycerides occur to the extent of over 8%, and the minor component acids are very uniformly distributed throughout the glyceride components of the oil. Data obtained from lipase hydrolysis in experiments have indicated a marked tendency for the 2-position in the triglyceride molecule to be occupied by an unsaturated acid, and there is some indication of overall selectivity of linoleic over oleic acid to occupy this position in cottonseed oil. Work underway using both U. S. and Indian cottonseed oils of different mean unsaturation is expected to shed more light on this tendency. The information from this research is expected to prove useful in the selection and processing of cottonseed oils for

the commercial production of improved salad oils in optimum yields. (UR-E29-(40)-26).

In P.L. 480 research at the University of Bombay, studies are being made of the relationship of the substituent fatty acid groups to the physical properties of diacid triglycerides of certain saturated fatty acids, including those that occur normally in cottonseed oil. The diacid triglycerides that are of interest in this work are those containing one or two molecules of palmitic or stearic acid, and two or one of even-carbon saturated fatty acids of the series from acetic to stearic acid. A number of such diacid triglycerides of both the symmetrical and unsymmetrical configuration have been prepared and purified to around 99.8% purity, as determined by the most sensitive available methods. Physical properties such as melting point (of the β form), density, molar volume, refractive index, molar refractivity and viscosity have been obtained for 40 pure glycerides. The data thus obtained will be of fundamental value as the basis for the further development of fats and oils specifically tailored for special food and industrial end uses. (UR-A7-(40)-3).

4. Investigation of Occurrence, Determination, and Properties of Fungi and Toxic Fungal Metabolites Which May Develop in Cottonseed and Its Processed Products. Considerable progress has been made in research investigations of fungi and toxic metabolites which may develop in cottonseed and its processed products. Aflatoxins were detected in several commercial cottonseed meals and in kernels from seed cotton exhibiting yellow-green fluorescence on the lint. Probing experiments were conducted to obtain information on the growth of fungi and elaboration of toxic metabolites in various cottonseed products: under favorable growth conditions, high levels (500,000-800,000 ppb) of aflatoxins B₁ and G₁ were produced on autoclaved or unautoclaved, glanded or glandless seed and kernels; somewhat lower levels (60,000-100,000 ppb) on meals or hulls; and quite low levels (100-300 ppb) on lint or linters. Levels of more than 2,000,000 ppb were obtained on shredded wheat. The aqueous acetone procedure previously developed for the determination of aflatoxins in cottonseed products was improved to permit analysis of aflatoxins at levels below 1 ppb and is applicable to numerous products. A micro procedure recently developed permits aflatoxin determinations to be made on as little as one milligram of material.

Preliminary results indicate that aqueous acetone extraction will simultaneously remove aflatoxins and gossypol pigments from cottonseed before the oil is removed. Meals free of aflatoxin, low in residual gossypol, light in color, and high in available lysine have been prepared, along with light-colored crude oils equivalent to many refined oils. Work has also been initiated on the fate of aflatoxins in soapstocks. Preliminary results indicate that aflatoxins are considerably modified by commercial alkali refining. Plans include the further improvement of analytical methodology--particularly the development of objective assay--as well as preparation of better working standards, increasingly efficient removal of aflatoxins from cottonseed and its products, determination of the limiting conditions for

for elaboration of toxins in cottonseed products, and study of the possible value of cottonseed having a hard seed coat. (S4 1-116).

B. New and Improved Food Products and Processing Technology

1. New Edible Oil Products Including Confectionery Fats, Food Coatings and Other Specialty Products. Further research has been conducted to develop processes for producing improved cocoa butter-like fats from cottonseed oil. The research on confectionery fats is supported in part through a Fellowship sponsored by the National Confectioner's Association.

Substantial quantities (10 lbs.) of cocoa butter-like fat were prepared by the previously developed directed esterification process. Operating conditions were found which should be suitable for use in large-scale preparations. The reaction products consisted of about 80% of the components desired in good cocoa butter-like fats and could be further purified by a fractionation (crystallization) process to yield products having the properties desired of confectionery fats.

Preparation of a good cocoa butter-like fat by a relatively simple process of hydrogenating a stearine obtained during the commercial solvent winterization of cottonseed oil under special conditons and purifying the hydrogenation product has aroused much industrial interest and should provide a new market for a significant proportion of cottonseed oil. Several firms are investigating potential commercialization of the new process. Eight hydrogenation runs on the stearine showed that a 4- to 8-fold scale-up in the batch did not affect the results, nor did the absence of solvent under the conditions used so far. The hydrogenation products, which were crystallized from petroleum ether or commercial hexane to remove most of the high-melting portion, all contained a large proportion of good cocoa butter-like fat.

A series of extractions was made to determine the best solvents and temperatures to use for removal of most of the high-melting portion from the hydrogenation product. This extraction procedure showed that the point of complete melting of the cocoa butter-like fat may be controlled by the temperature at which the solvent fractionation is conducted, but that changing the point of complete melting does not change the beginning of melting. (S4 1-125).

New and improved techniques for preparing useful derivatives of cottonseed and peanut oils by esterification and interesterification are being investigated. It has proven possible to effect direct esterification of amylose with palmitic acid by dissolving the amylose in dichloroacetic acid and reacting with excess fatty acid in the presence of 0.4% p-toluenesulfonic acid catalyst and boiling hexane. The products contained 54-56% combined palmitoyl groups (about 0.83 D.S.), but yields were only 20-25%. Other catalysts tried were less effective. Diglycerides such as distearin, diolein, dilaurin, and dicaproin were prepared and purified so that the

course of their catalytic esterification with fatty acids could be determined. Equimolar quantities of diglycerides and fatty acids were reacted under catalysis while heptane vapors were passed through the mixture. This series of reactions showed that interesterification occurs during the first few minutes of the reaction; to help minimize it, moisture must be removed from the reactants more efficiently than in these tests. An increase in the flow rate of heptane vapors passed through the reactants also decreased interesterification. The data obtained thus far indicate that more interesterification occurs than found by previous investigators. To establish the effect of temperature on the rate of esterification and the occurrence of interesterification, a reaction at 140°C. was conducted. The efficiency of various catalysts, mostly of the sulfonic acid type, is being evaluated, and some refinements in purification and analytical procedures have been achieved. (S4 1-128).

Development of fat emulsions having increased stability and good physiological properties should facilitate their adoption for intravenous nutrition and improve the prospects of utilization of cottonseed oil in such emulsions. Such research is being conducted cooperatively with the U. S. Army Medical Research and Nutrition Laboratory and research groups from several medical schools and is supported by the Office of the Surgeon General. Although emulsions of (a) commercial cottonseed salad oil (SR 152), (b) this oil washed with ethanol-water, (c) a commercial refined-bleached-winterized cottonseed oil washed with ethanol-water and laboratory-deodorized and (d) soybean oil (SR 151) gave satisfactory performance in long-term physiological evaluations, they caused undesired decreases in blood pressure of dogs. An investigation of the cause of this was therefore initiated. Since it was found that emulsions of cottonseed oil from glandless seed produced only mild effects on blood pressure it is presumed that the pigments and polar components present in conventional cottonseed oils are responsible for the adverse effects on blood pressure. Consequently, fractionation of commercial cottonseed salad oil by column chromatography was investigated as a method more effective than washing for removal of the objectional constituents. Results indicate that a combination of bleaching earth and alumina removed essentially all of the polar materials and most of the pigmentation. Emulsion SR-188 prepared with the fractionated oil was tested for blood pressure effects and found to be comparable to the emulsion prepared with the oil from glandless cottonseed. Long-term physiological evaluations of SR-188 are now in progress. Improvements in the method of removing pigments and polar materials from cottonseed oil are being sought. (SU-0-0-2(SG)).

2. Processing Technology Related to Improved Oil Products, Including Modifying or Eliminating Cyclopropene Acids in Cottonseed Oil. Plant-scale tests conducted on the alumina bleaching process for off-colored cottonseed oils have demonstrated the feasibility of the process for commercial use. Despite the use of existing refinery equipment poorly adapted for the process, the tests on bleach-resistant refined oil showed the superiority of alumina bleaching over bleaching with the best grade of acid activated

clay. Treatment with 2% and 4% of activated alumina gave bleached oils having Lovibond red colors of 3.1 and 2.2, respectively, as compared to colors of 3.4 and 2.8, respectively, by treatment with equal quantities of activated earth. Subsequent laboratory tests have shown that in properly designed equipment, using the same oil and alumina, a bleached oil color of 2.5 red is obtainable with 2.0% of alumina and a color of 1.6 red with 4% of alumina. Close cooperation is being maintained with the major vegetable oil producer and processor who conducted the plant-scale evaluations of the process.

Recent laboratory experiments indicate that the bleaching efficiency of alumina gel precipitated from aluminum sulfate with sodium hydroxide is significantly greater than that of any commercially available alumina. Also, "Baymal"--a special fibrillar colloidal boehmite alumina--used in conjunction with activated alumina gave even better results, reducing the color of a 6.6 red oil to 0.3 red. Of several chemicals employed in conjunction with activated alumina, sulfurous acid was the most effective in reducing malvalic acid content of cottonseed oil; however, the reduction was only 80%. (S4 1-114).

Further progress has been made by the contractor (University of Illinois) on chemical investigations of cyclopropenoids to develop means of eliminating or physiologically inactivating these type constituents present in cottonseed products. Structural analysis of the three major pigmented compounds isolated from the Halphen-test reaction of 1,2-diethylcyclopropene has continued. One of the compounds was identified as cis-1,5-diethyl-2,4-dithiobicyclo(3.1.0)hexane-3-thione. A second compound has been tentatively identified as a resonance hybrid of 1,2-diethylcyclopropyl 5-ethyl-3-(thioacetyl)-1,2-dithia-3,5-cyclohexadien-6-yl thioether and 1,2-diethylcyclopropyl 2-ethyl-4,5-cyclodithia-2,4-hexadienedithioate. The third compound has not yet been identified.

In other studies of the chemistry of cyclopropenoids by the contractor, the cyclopropene moiety of sterculene (1,2-dioctylcyclopropene) was partially protonated and cleaved when refluxed for five hours with benzene and acetic acid, but a small amount of perchloric acid greatly increased the speed of the reaction, even at room temperature. In both cases, the reaction products contained 9-methylene-10-acetoxyoctadecane, 9-methylacetoxy-9-octadecene, and 9-methyl-10-acetoxy-9-octadecene. The perchloric acid-catalyzed reaction also produced a small quantity of 9-methylacetoxy-10-octadecanone. It was found that formic acid will slowly protonate and cleave the cyclopropenoid moiety of sterculene at room temperature in the presence of an aqueous hydrogen peroxide or perchloric acid catalyst. Similar type acyloxy derivatives described above are obtained; but, in addition, the hydrogen peroxide catalyst causes the formation of 9-methylene-10-octadecanone. Based on these fundamental findings, Halphen-negative cottonseed oil was prepared by reacting 100 milliliters of cottonseed oil, 10 milliliters of acetic acid, and 1 milliliter of perchloric acid at room temperature for 2 hours. The oil was slightly brown after treatment.

A sensitive photometric procedure developed for the analysis of small quantities of cyclopropenoids could prove useful for assaying cottonseed oil for its cyclopropene content. (S4 1-107(C)).

3. Cottonseed Flours and Derived Products for Human Consumption in Developing Countries. A recently initiated study of the preparation of cottonseed flours and their derived products for human consumption in developing countries, which is supported by the Agency for International Development (AID), has produced some promising results. Current research is being directed to developing simplest types of screw pressing and solvent procedures, including 2-stage extraction processes, suitable for small or medium size extraction plants to produce defatted or partially defatted flours. Four of the procedures have been used on a bench-scale to prepare small lots of cottonseed flour, which were submitted to the Human Nutrition Division to be evaluated in biscuits, noodles, tortillas, unleavened bread, yeast bread, and cookies. Preliminary results indicate improvements are probably necessary in flavor and color for the yeast breads and perhaps other products. Two larger lots of cottonseed flours have been made in the pilot plant for UNICEF using the hexane-acetone-water mixed solvent extraction process. One is being evaluated in Peru as the sole source of protein in infant feeding over an extended period of time and results show it is practically equivalent to milk protein. UNICEF is presently having these flours evaluated in Peru, Egypt, Italy, Guatemala, England, and other countries, as well as in the U. S. A. The flours are high in protein and available lysine content, low in fiber, low in free and total gossypol, and show no detectable amount of aflatoxin. Pilot-plant scale equipment is currently being procured and assembled in an enclosed area to enable the production of the flours under sanitary conditions. (SU-0-0-3(AID)).

C. New and Improved Feed Products and Processing Technology

1. Basic Research to Improve Nutritive Value of Cottonseed Meal for Poultry and Swine, Including Investigations of Physiologically Active Constituents. As a basis for improving the nutritive value of cottonseed meal (and flour), research is continuing on the chemical composition and characteristics of the protein systems of cottonseed. Completed analyses of the amino acid and fatty acid constituents of the species of Gossypium that can be induced to cross with upland cotton show that there is no amino acid or fatty acid pattern characteristic of the genus. Significant range between species has been encountered in the limiting amino acids and in the major fatty acids. This knowledge provides an opportunity to modify genetically the composition of commercial cottonseed to improve the nutritive value of the meal and increase the versatility of the oil.

Other work has been directed toward obtaining a thorough understanding of the effect of lipid extraction on nitrogen solubility and the nature of the nitrogenous materials of cottonseed. It was found that hydration of cottonseed before defatting decreased the percent lipid extracted by non-polar solvents but had no effect on the percent nitrogen extracted by water from the defatted material. Hydration increased the percent non-nitrogenous

materials extracted by polar solvents or solvent mixtures, producing a protein concentrate, but decreased the percent nitrogen extractable by water from the defatted material. Gel electrophoresis demonstrated the presence of ten major protein components in the water soluble fractions at pH 6.8 or 8.7. Evidence was obtained for the presence of a proteolytic system which selectively hydrolyzed two of the ten components.

The Sephadex G 200 profile of the water soluble portion of defatted cottonseed in pH 8.9 buffer, using the Lowry procedure for measuring protein, was arbitrarily divided into six fractions. Gel electrophoresis of the fractions substantiated the fractionation of the protein components, the major portion of which are found in Fractions III, IV and V. Fraction VI, a major Lowry positive fraction, was shown by dialysis, ninhydrin, and anthrone tests to be composed of free amino acids, peptides and carbohydrates. Hydration of the seed before defatting with the same solvent decreased Fractions II and III of the Sephadex profile and changed the amino acid profile. Cystine and the basic amino acids increased, and valine, isoleucine, and leucine decreased in the water soluble fractions. The native enzymatic activity in the water soluble fraction, demonstrated under sterile conditions, causes a major decrease in Fractions II, III, and IV and a concurrent increase in Fraction VI in the Sephadex profile after incubation in pH 6 Tris buffer for 72 hours. Ten meals have been prepared from quiescent and hydrated glandless seed by batch extraction with polar and nonpolar solvents for nutritive evaluation in cooperation with the Ralston Purina Company. A trainee supported by UNICEF has participated in this research. (S4 1-130).

Investigations to isolate and identify the factors in cottonseed meal that cause mortalities among swine have continued, in cooperation with the Pharmacology Laboratory at WU, the Animal Husbandry Research Division, ARS, and the Ralston Purina Company. The rate of growth of swine receiving cottonseed meals as their protein supplement in rations based on cereals may be predicted satisfactorily on the basis of available lysine in the meal proteins, but this test is not satisfactory since mortalities occur among swine receiving certain cottonseed meals without there being a correlation between the deaths and the protein quality of the meals. Several cottonseed meals causing mortalities in swine feeding experiments were fed to protein-depleted rats, but produced no indication of toxicity. The protein efficiency ratio, as determined in the protein-repletion tests on rats, ranged from 1.17 to 1.93 for commercial cottonseed meals and from 2.58 to 2.74 for the cottonseed meals prepared by acetone-hexane-water solvent extraction, as compared with a value of 2.45 observed for a selected soybean meal. Analyses of tissues of rats that have received cottonseed meals lethal to swine were continued, but no conclusions have been reached.

Feeding swine soybean meal combined with gossypol in different treatments has indicated that the physiological activity depends on the manner in which the combination takes place. Total gossypol found on analysis of the soybean-gossypol complex is always less than the quantity of gossypol added. The nature of the combination of gossypol and meal constituents that gives rise

to physiologically active gossypol derivatives has not been determined.

Albumin components of egg white proteins migrated into the yolk through the blastoderm of eggs produced by hens ingesting soybean meal-cottonseed pigment gland mixtures. Abnormalities in the eggs produced by such hens included pH change in the yolk and whites, but not the fatty acid patterns of the yolk fat. It appears that a good estimate of the value of a cottonseed meal for broiler rations may be obtained from a knowledge of the available lysine level. Some sources of error in the published method for determining available lysine have been identified; at the 1% level of probability, the confidence limits for reproducibility are ± 8 parts in 375. (S4 1-110).

2. Processing Technology Directed Toward Improving Meals. An investigation recently initiated is designed to determine processing conditions for the production of oils and meals of maximum quality from glandless cottonseed, in cooperation with the National Cottonseed Products Association; the Human Nutrition Research Division, ARS; and UNICEF. This type of cottonseed, from which gossypol has been removed genetically offers an outstanding opportunity to the cottonseed industry to improve the quality of its products and to expand and strengthen markets. A lot of 4,400 pounds of the glandless seed was solvent-extracted to produce about 1,200 pounds of low-lipids and high-lysine content meal. Mixed solvent was used for this extraction to insure simultaneous removal of approximately 6 parts per billion mycotoxin found to be present in the meats. The meal will be ground to flour, sterilized at 180°F. and shipped to Guatemala for experimental use in human food formulations. Bench-scale equipment is being assembled to determine optimum preparation, extraction, and desolventization conditions for processing glandless cottonseed by screw-pressing, prepress extraction, and direct extraction. Various extraction methods and various solvents will be studied. Parallel studies will be carried out with glanded seed, which are known to require limited use of heat and moisture in processing because of the deleterious effects of gossypol on both oil and meal or flour quality. (S4 1-127).

The inactivation or removal of aflatoxins from contaminated cottonseed and its products is requisite to their being used in feeds (and foods). Treatment with chemicals, especially those based on ammonia, appear to be effective in reducing the aflatoxin content of contaminated cottonseed meals without significantly altering their nutritive value. Cottonseed meal containing 145 ppb of aflatoxin B₁ was treated with 5% by weight based on the meal of the following reagents by themselves and in combination: Ammonium salts (carbonate, acetate, chloride), urea, calcium hydroxide, and sodium sulfite. Four reaction conditions were used which varied time, temperature, amount of water used, and the type of vessel, i.e. open with stirring vs. closed. Control reactions (no reagents used) under all conditions reduced the aflatoxin B₁ to 74-80 ppb. The most effective treatment appeared to be a mixture of sodium sulfite and ammonium chloride, yielding a product containing 27 ppb of B₁. Ammonium carbonate and calcium hydroxide appeared less effective (36 ppb) under the best treating conditions. Addition of urea had no effect. A mixture of soyflour and cottonseed meal (1:2 ratio) after

heating with added moisture yielded a product containing 36 ppb. Anhydrous ammoniation also produced good results with cottonseed meal: this treatment reduced the aflatoxin content from 145 ppb B₁ to no detectable B₁. Future work will be directed toward developing practical methods for inactivation of aflatoxin by chemical treatments, especially those based on alkalies. Feeding studies will be conducted in cooperation with WU and other groups to better define the conditions required for destruction of aflatoxin without impairing nutritive value. (S4 1-133, Pending).

Contract research is being conducted by the Illinois Institute of Technology Research Institute to develop practical processing methods for inactivating cyclopropene groups in cottonseed meal. The development of an accurate and sensitive procedure for detecting low levels of residual cyclopropenoid fatty acids (CPA) in cottonseed meals is essentially complete; this analytical procedure furnishes an essential research tool for determining the efficiency of chemical inactivation or extraction procedures. Prior research at SU aided in this development. Basically the procedure involves Soxhlet extraction of residual lipids with methanol, preparation of methyl esters in the methanol extract by transesterification with sodium methoxide, isolation and purification of methyl esters to remove interfering pigments, followed by spectrophotometric determination of CPA by use of a sensitive Halphen reaction. As little as 1×10^{-4} grams of CPA can be detected by the Halphen reaction. Typical commercial cottonseed meals were found to contain residual CPA ranging from 0.001 to 0.020%. The analytical procedure should be capable of detecting levels as low as 0.0001% residual CPA in treated meals. Work has been initiated on laboratory-scale experiments to inactivate or remove residual CPA in commercial cottonseed meals. (S4 1-117(C)).

Research is continuing on the rates of extraction of oil of cottonseed with acetone-hexane-water solvent mixtures and on the properties of the resulting marcs and miscellas. Material balance studies on a 4-step countercurrent extraction of raw moist cottonseed flakes, where the vibrating screen separation procedure was used, showed that extraction of oil is very rapid and substantially complete; residual oil in the air-dried marc is reduced to a very low level by light pressing between each pass in the countercurrent extraction; and the miscellas and crude oil are relatively stable, no color fixation being noted for weeks during storage. Fines did not accumulate during continuous operation when the miscella was recycled at the third step of the process. Ten-step countercurrent extractions of raw moist cottonseed flakes with the azeotrope were also carried out in the basket centrifuge with solvent-to-flakes ratios of 3:1, 2:1 and 1.25:1. Residual oils in the final marcs were less than 0.1% for solvent-to-flakes ratios of 3:1, and 2:1, and about 0.2-0.3% for solvent-to-flakes ratio of 1.25:1. Optically clear miscellas were obtained. Total gossypol values in these marcs (air-dry basis) ranged from 0.1 to 0.25%. The quantitative extraction of oil from moist raw cottonseed flakes can be achieved with azeotrope in a continuous extraction with a residence time of about 3 minutes. Use of the mixed solvent should point the way to a greatly improved processing method for oilseeds, and the superior nutritional quality of the cottonseed meal should lead to its

increased utilization in swine rations. (S4 1-123).

D. New and Improved Industrial Products and Processing Technology

1. Research to Develop New Reactions and Products Suitable for Industrial Use. Nineteen additional symmetrical N,N-disubstituted long chain amides were prepared, characterized, and evaluated as plasticizers for polyvinyl chloride and will be submitted for antimycotic-activity screening. Plasticizer performance has now been determined for the N,N-dibutyl amides of a number of pertinent long chain fatty acids including palmitic, stearic, linoleic, ricinoleic, erucic, epoxystearic and dimer acids, as well as Armour "animal acids" and parsley seed acids, rapeseed acids, Limnanthes douglasii seed acids, and selectively hydrogenated cottonseed acids. All except the stearic, linoleic, and ricinoleic acid derivatives passed the 30-day shelf-storage compatibility test. In general these amides are more efficient than DOP, and most of them, including those of the seed oil acids and "animal acids," gave very low brittle points, ranging between -51 and -63° C. They are thus comparable to dioctyl adipate (-55° C.) without the objectionably high volatility loss of the latter. Fifteen other long chain N,N-disubstituted amides, most of which were unsymmetrically N,N-disubstituted oleamides, were also prepared and evaluated. All passed the compatibility test.

The plasticizing characteristics of the various derivatives that contained one 2-acetoxyethyl substituent did not differ appreciably from those of the symmetrically disubstituted N,N-bis(2-acetoxyethyl)oleamide. The N,N-bis[2-(3-formylpropionyloxybutyl)ethyl] and N,N-bis[2-(3-formylpropionyloxyhexyl)ethyl] oleamides gave somewhat less satisfactory low temperature performance than the N,N-bis(2-acetoxyethyl) derivative but were more resistant to soapy water extraction. Exploratory experiments have markedly improved the commercial attractiveness of such plasticizers by showing that an efficient stabilizer can be prepared. A commercially available dibutyl tin mercaptide stabilizer used in conjunction with an alkylarylphosphite chelator provided excellent thermal stability to polyvinyl chloride resins plasticized with N,N-dibutyloleamide.

Twelve trial compositions (4-propylpiperidides and mixed 2-methyl-3(5)ethylpiperidides of six commercial fatty acids) were evaluated as polyvinyl chloride plasticizers for a chemical company to assist them in selecting the best ones for preparation on a pilot-plant scale for test marketing. The two compositions rated best were made from the cheapest fatty acids; one of these will soon be sample-distributed by the company and in large volume will be competitive in price with DOP. These commercial evaluations have resulted largely from earlier SU research on piperidides of long-chain fatty acids. (S4 1-124).

Contract research sponsored jointly by SU, NU, EU and WU seeks to extend the industrial utilization of agricultural products in commercial plastics through an investigation of the free-radical high-pressure copolymerization of ethylene with unsaturated fatty acids and other selected, commercially

available agricultural monomers. The contractor (U. S. Industrial Chemicals Corp.) has completed copolymerization runs at three ranges of comonomer concentration (3%, 10%, and the maximum feasible) for methyl oleate, methyl undecenoate, methyl esters of the acids of tung, castor, dehydrated castor, safflower, conjugated safflower, and linseed oil. Maximum concentration of monomers for stable reaction was 31, 40, 15, 29, 26, 24, 20, and 19, respectively. The more unsaturated or the conjugated monomers adversely affect the concentration and efficiency of the catalyst. Although the less unsaturated monomers produced more interesting products, the molecular weight of all products was too low to permit use as blown film; some, however, may offer promise for less conventional plastics applications. Plans include the polymerization of ethylene with vinyl laurate and erucylamide and further evaluation of the more promising monomers. (S4 1-115(C)).

Research under another contract (University of Arizona), also sponsored jointly by the four Divisions, has produced considerable information on the polymerization of vegetable oil derivatives for use as elastomers, plastics, thickening agents, or protective coatings. Samples of copolymers of vinyl esters of nonhydroxy carnauba wax acids and of pure saturated C₁₈ cyclic vinyl esters, supplied by NU, with vinyl chloride were prepared for evaluation. The vinyl ester of the cyclic acid obtained by the addition of ethylene to tung oil has also been prepared and purified by reprecipitation for determination of physical properties. Research on the polymerization of monomers from fats will be continued under a new contract. (S4 1-89(C)).

A fundamental investigation of the chemistry of gossypol and its derivatives having potential industrial utility is now nearing its final stages in a P. L. 480 research project being conducted at the University of Montevideo, Uruguay. A large number of derivatives of gossypol, many of which have not been heretofore reported, have been prepared and characterized. Among these are 24 new imino derivatives, 8 new ester derivatives, along with cyanohydrin and hydantoin compounds. Derivatives have been screened for potential usefulness as fungicides, germicides, ultraviolet screening materials and as potential anti-cancer agents. Gossypol, the yellow primary pigment of cottonseed, can be made readily available by isolation from byproducts of cottonseed oil refining. The information gained in this project may indicate promising industrial or other uses for this chemically reactive natural pigment. (UR-S9-(40)-2).

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^{2/} Publication resulting from research supported by funds transferred from the Office of the Surgeon General.

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HOME CARE OF TEXTILES: CHEMICAL AND MICROBIOLOGICAL PROBLEMS

Clothing and Textile Laboratory, NCIU, ARS

Problem. The family's supply of clothing and household textile items represents a considerable initial investment and requires a never-ending expenditure of time and money for keeping it in good condition. Reliable information about laundry aids, such as detergents, bleaches, and fluorescent brighteners for household use, is therefore in great demand. Requests are also received for information on removal of pesticide residues from work clothes. To furnish guidance to consumers on selection and use of appropriate agents, more needs to be known about the nature of soils, stains, and contaminants, and their removal from cotton, wool, and other fabrics. Environmental and other factors that accelerate undesirable changes in appearance or other properties of textile materials, and on means to prevent such changes should be investigated. As textiles are potential disseminators of pathogenic and odor-producing microorganisms, investigations are needed on factors influencing their survival on fabrics, and on methods suitable for consumer use, for controlling such transmission.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing program to investigate 1) the nature of soil and its removal from fabrics, 2) the nature, causes, and prevention of undesirable changes in fabrics, and 3) the role of fabrics in the dissemination of microorganisms and means of control. Fabrics differing in construction, fiber content and finish are used in the work. Families and individuals cooperate in studies of natural soiling of clothing and household textiles, and of home-type laundering.

The research effort, totaling 6.5 professional man-years, one of which is devoted to basic research, includes chemists, microbiologists, and textile specialists. Their headquarters is at Beltsville, Md.

PROGRAM OF THE STATE EXPERIMENT STATIONS

The States have only a limited program in this area. In the Western region researchers have prepared an outline for a regional project designed to study the efficiency and cost of laundering as related to differences in water quality, wash water temperature, and type of detergent. The current consumer interest in laundering at low wash-water temperatures, as well as the availability of detergents that are relatively more biodegradable, combine to make this a most timely proposal.

Non-regional research includes studies on the effect of heat, light, solvents and laundering on laminated apparel and household textile articles; and on the evaluation of fabrics treated with antibacterial agents. One State is carrying out basic research on the nature of the residual soil on laundered fabrics and on the method of its attachment to the fibers.

The total State program in fiscal 1964 was 1.7 professional man-years.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Removal of Soil and Prevention of Undesirable Changes in Textiles

To supply quantitative information for more efficient and safer use of liquid chlorine bleaches, studies on the interactions between cotton fabric, four soils and sodium hypochlorite continued. Both damage to the fabric and yellowness varied with the type of soil, pH of the hypochlorite solution and total amount of available chlorine which reacted with the fabric.

Studies on the whitening effects of ten fluorescent compounds on unsoiled fabrics were completed. Effectiveness of three stilbene and three coumarin whiteners was adversely affected by sodium hypochlorite. Therefore these six chemicals produced greater whiteness when the bleach was added to the wash several minutes after addition of the whitener. On the other hand, the benzimidazole, benzoxazole and benzidine sulfone whiteners retained all or most of their whitening activity in the presence of hypochlorite bleach. Hence, it was not necessary to delay addition of the bleach.

Three manuscripts were cleared for publication: Color Effects of Different Fluorescent Whiteners; Yellowing of Fabrics During Storage; and Effect of Sodium Hypochlorite Solutions on Soiled and Unsoiled Cotton Fabrics. Three articles were prepared for the 1965 Yearbook of Agriculture, Consumers All: Hidden Damage, Removing Stains, and Soaps and Syndets.

B. Dissemination of Microorganisms by Fabrics

Studies on the factors that influence redeposition of bacteria on fabrics during laundering were continued. The force with which bacteria come in contact with the fabrics appeared to be the critical factor, with fiber type, water temperature, presence of soil, and fabric construction next in importance. The laboratory procedures developed are suitable for simulated in-use evaluation of disinfectants.

More bacteria was recovered from fabrics washed at 55° F. than at 130° F. under both simulated and in-use conditions.

Studies on the microbiology of drycleaning continued. Data were obtained on the numbers and kinds of microorganisms present in the solvents and in the fabrics at different points in the cleaning units, and after steam pressing. In most cases several factors, especially steam pressing, combined to reduce the number of bacteria to a low level. However, in certain areas of some garments an appreciable number of bacteria survived all stages of drycleaning. As in laundering, bacteria are transferred from one fabric to another during drycleaning.

Studies on the persistence of viruses on fabrics continued under contract. In general, both viruses survived longer on woolen than on cotton fabrics. Poliomyelitis virus persisted on wool fabrics as long as 20 weeks and on cotton fabrics as long as 4 weeks. Vaccinia virus persisted on wool fabrics as long as 14 weeks and on cotton fabrics as long as 10 weeks. The method of exposure (contact, aerosol, contaminated dust), relative humidity and type of fabric affected the duration of viral persistence on the fabrics.

Four articles were submitted for publication: The Microbiology of Drycleaning; Survival of Bacteria in Cold Water Laundering; Quantitative Studies on Fabrics as Disseminators of Viruses I. Persistence of Vaccinia Virus on Cotton and Wool Fabrics, and II. Persistence of Poliomyelitis Virus on Cotton and Wool Fabrics.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Removal of Soil and Undesirable Changes in Textiles

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CLOTHING, HOUSEHOLD TEXTILES, AND FABRICS FOR CONSUMER USE

Clothing and Textile Laboratory, NCIU, ARS

Problem. The ever increasing variety of fibers, constructions and finishes used in household textiles and apparel, makes decisions by consumers more and more difficult. The mandatory labeling of textile products as to fiber content only partially solves the problem. To obtain maximum benefit from such labeling, consumers need information on the properties imparted to textiles by different natural and manmade fibers, fiber blends, fabric constructions and finishes, and on the properties textiles need for satisfactory performance in specific uses.

USDA AND COOPERATIVE PROGRAMS

Investigations include studies of the relationship of in-use performance of fabrics of known fiber type, construction, and finish with laboratory determinations of such properties as elastic behavior, dimensional stability and resistance to abrasion. Changes in appearance and other properties during use are followed both subjectively and objectively. Rapid and dependable methods for predicting performance in use are sought. Principles of construction for use in making, repairing, or altering clothing and household textiles are developed. Special attention is given to problems related to consumer use of clothing and household textiles made from cotton and wool.

The Federal scientific effort in this area, totaling 1.0 professional man-years, is devoted to basic research with headquarters at Beltsville, Md.

PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in basic and applied research on textile fibers and on the end-use performance of clothing and household textile articles.

Textile specialists in the Southern region are completing a study on the relationship of such fiber properties as elongation, tear resistance, breaking strength and abrasion resistance to end-use performance of fabrics made from fibers of known physical properties. The results of such research are of importance to both cotton producers and consumers.

Researchers in the Western region have completed a study of the role of such environmental factors as light, temperature, relative humidity and air pollution in the degradation of cotton fabrics. A manuscript is in preparation.

In the North Central region work is in progress on the effect of repeated stresses of small magnitude (e.g., torsional, abrasive, tensile) on the behavior of fabrics of different fiber types and construction. Since such stresses do occur under in-use conditions (bending, stretching, etc.) results of such research should provide basic information that may be used in predicting fabric performance.

Textile specialists and social scientists in the Northeastern region are collaborating in a study of the attributes of consumer satisfaction in relation to laboratory and in-use performance tests of certain household textile articles. The results of this research will provide useful information for both consumer and manufacturer.

Non-regional studies deal with: service qualities of soft floor coverings including development of an accelerated laboratory procedure designed to predict in-service performance; dimensional stability and thermal transmission of cellular constructed blankets; a possible relationship between air permeability and fiber degradation; electric properties of cotton fibers; a comparison of the serviceability of garments made from stretch fabrics with those made from non-stretch ones; the relation of price to quality characteristics of selected fabrics.

The State program focuses on fiber and fabric properties as related to consumer-use problems. The total State research in this area involved approximately 22.1 professional man-years, with 24 States contributing. Over two-thirds of the federally supported projects contribute to regional programs.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Performance of Fabrics for Clothing and Household Textiles

Studies on elongation and elastic recovery of plain and double knit cotton fabrics were completed, and the results summarized for publication. Elongation and growth increased inversely with the ratio of diameter of yarn to stitch length cover factor. This information provides a basis for control of elastic properties of knit fabrics.

Two manuscripts on serviceability of cotton and wool fabrics were submitted for publication: The Effect of Yarn and Cloth Construction on Properties of Apparel Fabrics of Deltapine 15 Cotton. Part I: Laboratory Evaluation of Nine Shirtings; and Slip Covers Made of 35 Fabrics.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Performance of Fabrics for Clothing and Household Textiles

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III. MARKETING AND ECONOMIC RESEARCH

COTTON AND COTTONSEED - MARKET QUALITY

Market Quality Research Division, ARS

Problem. Technological advancement in production, harvesting, and ginning, of cotton brought on by mechanization has resulted in changes in the quality of cotton fiber which are not recognized by present methods of quality evaluation. Mill operators, both domestic and foreign, have reported that these changes have reduced the spinning quality of cotton, thus increasing processing costs and lowering the value of finished products. Precise information is needed on the processing performance and manufactured product quality of cottons which have been subjected to various production, harvesting, and ginning practices in preparation for markets. New and improved techniques, devices, and procedures for measuring quality factors of cotton fiber are needed to provide better grading and standardization of lint cotton, and indicate the true processing performance and manufactured product quality.

Cottonseed is subject to deterioration in quality and loss in value through fungus damage and contamination, normal metabolic changes, and instability of its oil constituents when exposed to the atmosphere. To maintain its quality, more precise information is needed on the environmental factors which influence these changes during handling, storage, transportation, and processing. Also, to insure uniform and standardized products in the marketing channels, new and improved methods for measuring quality factors need to be developed for use in inspection, grading, and standardization programs.

USDA PROGRAM

The Department has a continuing program involving textile engineers, cotton technologists, chemists, and engineers in basic and applied research on objective measurement and evaluation of quality of cotton fiber and on the quality evaluation and quality maintenance of cottonseed. The research is conducted at Washington, D. C., Lubbock, Texas, Auburn, Alabama, and at Clemson, South Carolina, in cooperation with Clemson University, and by research contracts with Clemson University, Texas Technological College and Auburn University.

The program includes the following foreign projects under P. L. 480: A grant to Centre de Recherches des Industries, Rouen, France, provides for an investigation of fiber maturity and breakage during mechanical processing of cotton, and the relation of these factors to processing performance and product quality. Its duration is 4 years, 1961-1965, and involves P. L. 480 funds of \$64,500 equivalent in French francs.

Another grant to the same institution provides for development of an instrument for homogenizing and orienting fibers in samples for cotton testing. Its duration is 4 years, 1961-65, and involves P. L. 480 funds with a \$47,000 equivalent in French francs.

A grant to the Fiber Research Institute, T.N.O., Delft, Holland, provides for a study of the influence of length properties on the mill processing performance of cotton. Its duration is 3 years, 1962-1965, and involves P. L. 480 funds with a \$58,000 equivalent in Dutch guilders.

The Federal scientific effort devoted to research in this area totals 20.2 professional man-years subdivided as follows: cotton 17.7, with 4.7 under research contract and cottonseed 2.5.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

State stations are engaged in developing breeding stocks and varieties for both upland and long staple types of cotton. The influence of climate, cultural practices, and harvesting, and storage conditions on yield and quality of fiber received much research attention. Mechanical harvesting effects are evaluated by study of fiber properties and through spinning tests. Fiber samples from the breeding and cultural studies are submitted to State and Federal laboratories for testing of fiber and spinning properties. The Tennessee station is giving special attention to devising new and better tests and improving equipment for measuring properties now considered standard in fiber testing. One study is devoted to developing germination tests for cottonseed and measuring seed quality. Another deals with seed cotton moisture content and the effects on cotton fiber quality.

Cottonseed is evaluated for quality and nutritive value--of particular interest is the study of the chemical properties and biological significance of gossypol and gossypol protein complexes. The quality aspect relates to feeding value and quality of the meal for farm animals.

Approximately 12.1 professional man years are devoted to quality evaluation of cotton and cottonseed.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurements and evaluation of quality of cotton

1. Effect of Various Production, Harvesting, and Ginning Practices on Cotton Quality and Spinning Performance. These studies, in cooperation with other agencies, are being continued by the ARS Cotton Quality Research Station, Clemson, South Carolina. Results are as follows:

(a) 1963 Defoliation Study. Preliminary analysis made of the 1963 early harvested cottons were similar to the results obtained from the 1962 defoliation study, indicating that the differences in fiber and spinning

qualities between undefoliated and defoliated or desiccated cottons were very small, although yarn strength tended to be slightly higher and spinning end breakage slightly lower for the undefoliated cotton. Similar trends were noted for the late harvested cottons. The micronaire reading was lower for the late harvested cottons than the early harvested cottons, with the lower micronaire readings being obtained on the defoliated or desiccated cottons. A report for these two crop years is being prepared.

(b) 1963 Foreign Matter Study. This study was designed to determine the effects of foreign matter on spinning performance, product quality, and cost of raw cotton. Two methods of trash removal were used: (1) by varying the gin cleaning equipment and (2) by using card crusher rolls. The test results showed that trash removal during ginning caused improvements in spinning performance when no noticeable fiber damage occurred. The use of card crusher rolls to further remove foreign matter resulted in improvements in spinning performance and yarn appearance regardless of the ginning conditions. The greatest improvement was noted for the trashier or minimum gin-cleaned cotton. A progress report on this work has been published. This study will be continued for another crop year.

(c) 1963 Bale Compression Study. This study conducted under contract by Texas Technological College, indicated that the level of bale density had no effect on fiber quality but did affect the weight of stock produced in process during opening and picking. After adjustments were made to control weight at picking and at drawing, the level of bale density did not affect yarn properties or spinning performance. A report is being prepared.

(d) 1964 Pima Ginning Study. Preliminary analyses of test results indicate that a reduction in lint moisture during ginning caused a reduction in foreign matter content and in fiber length but resulted in improvement in spinning performance. The amount of cleaning equipment used in this study had very little effect on fiber and spinning properties. A report is being prepared.

(e) 1964 Southeastern Picker-Stripper Study. Preliminary analyses indicates that the spinning end breakage ranged from 3 to 5 times higher for stripper-harvested cotton than for the spindle-picked cotton. The data are being further analyzed and a report will be prepared.

2. Spinning Methodology Studies. A methodology study was designed to determine the effects of fineness, length uniformity, and card crusher rolls on spinning performance and yarn properties. The results showed that when crusher rolls were used, an increase in micronaire reading or a decrease in length uniformity ratio caused spinning end breakage to increase for both 30s and 40s yarn. The effects of fineness were greater for 40s than for 30s yarn, whereas the effect of length uniformity was essentially the same

for both 30s and 40s yarn. When the crusher rolls were not used, neither fineness nor length uniformity significantly affected spinning end breakage for 30s yarn. Evidently, trash content overshadowed the effects of fiber properties for 30s yarn. For 40s yarn, end breakage increased with increases in micronaire reading and with increases in "nep-like" fragments (trash) in yarn. For yarn properties, an increase in micronaire reading caused a decrease in yarn strength, and an improvement in yarn appearance. A decrease in length uniformity ratio also caused a decrease in yarn strength. The use of crusher rolls reduced spinning end breakage and yarn imperfections but had no effect on yarn strength. A report on this work has been released. These methodology studies will be continued.

3. Investigation on Chemical Residues on Surface of Cotton Fibers. Techniques are being developed to better characterize the chemical nature of the cotton fiber surface in reference to chemical residues and inherent chemical composition. A practical, reproducible method for removal of cotton waxes was developed. During the year, many lots of cotton gave considerable trouble in spinning due to lap-ups and gumming of the rolls. A study was started to try to establish a relationship between the quantity and nature of the noncellulosic constituents of the fiber and the tendency to cause stickiness and lapping on spinning rolls. It was found that, in general, the low-micronaire cottons had high wax contents and a high percentage of alcohol-extractable materials, and these cottons lapped badly on the rollers during spinning. The low-micronaire cottons also lost much more weight in normal scouring and bleaching processes. Future investigations will include development and utilization of additional qualitative and quantitative techniques to aid in establishing relationships between the noncellulosic constituents of the cotton fiber and either spinning performance or product quality.

4. Measurement of Frictional Properties of Cotton Fibers. Work has continued on the development of methods for measuring drafting cohesion and short-term drafting cohesion variability. The use of multiple sliver feed has improved the testing efficiency. The electronic measuring system has been simplified and the cohesion tester has been redesigned to lower the inertia of the load-weighting system so that testing speed can be increased. Using this new technique for measuring drafting cohesion, card slivers from lots being processed in the Pilot Spinning Laboratory were tested. An analysis of the test results shows that drafting variability is related to fiber length variability and is related to measurements of yarn irregularity. A progress report is being prepared for publication.

5. Instrument Evaluation. Evaluation of the Fibrosampler and the Digital Fibrograph was continued. Suter-Webb array measurements, calculated on both weight and number basis, were compared with Digital Fibrograph measurements, which are on a number basis. The number of long fibers, rather than the weight of long fibers by array, was more highly related to break factor. The Digital 2.5 percent span length was as highly related to break factor as was the array upper quartile length. The weight of short fibers, rather than the number of short fibers by array, was more highly related to end breakage.

A manuscript is being prepared, giving suggested techniques for operating the Fibrosampler in order to maintain a constant level of test results on the same test sample with a minimum amount of testing error.

A progress report on the evaluation of the Outlook Trashmeter was prepared, jointly, with the Cotton Division, C&MS. Trashmeter measurements (4 observations per sample) were as good as Shirley Analyzer measurements in predicting picker and card waste and were more highly related to grade index than were the Shirley Analyzer measurements. The Trashmeter has good precision, but more than one reading per sample is necessary because of sample variation. Also, background color affects the level of the measurements.

6. Relationship of Fiber Maturity to Fiber Breakage During Mechanical Processing. Six bales of Acala 4-42 cotton representing 6 levels of maturity (micronaire readings) were investigated during this fiscal year and the results indicated the following:

1. Fiber breaking at reversals in the fibrillar structure is much greater for the mature cottons than for the immature cottons.
2. Spinning performance is more highly related to mean length of drawing sliver than to maturity of the cotton.
3. Fiber breakage during processing is much greater for the immature cottons than for the more mature cottons.

Two additional cottons are yet to be investigated.

7. Instrument for Homogenizing Test Sample. A research project is being conducted in France under a P. L. 480 project to develop an instrument for homogenizing and orienting cotton fibers in a sample for fiber testing.

A number of approaches to this problem have been investigated without success. The latest developments involving two instruments look very promising. One instrument involves mechanical means only and the other a combination of mechanical, pneumatic, and electrostatic means. These instruments are being evaluated and preliminary results indicate that very good opening, blending, and parallelization is being obtained without noticeable fiber breakage.

8. Influence of Fiber Length Distribution on Mill Processing. A research project is being conducted in Delft, Holland, under a P. L. 480 grant to study the influence of fiber length distribution on mill processing of cotton. The results obtained on the large-scale test showed that variants with cut fibers added gave higher number of end breakages at spinning than the corresponding variants with comber noils added for both the Acala and Deltapine cottons. In the case of the small-scale tests, the Acala variants gave the same trend as the large-scale test but the Deltapine variants gave the opposite trend. For weaving, the yarn breaks that can be ascribed to yarn itself is highly related to the number of weak spots in the yarn. Of all the yarn breaks, more than half of the total breaks were caused by the loosening of the knots. A paper dealing with this work was presented at the Cotton Research Clinic, held at Pinehurst, North Carolina, last February.

B. Objective measurement of quality of cottonseed

1. Method for the Rapid Measurement of the Refining Loss of Cottonseed Oil in Small Lots of Seed. An estimate of the amount of refined oil obtainable from cottonseed by a fast instrumental method is dependent upon a standard method for reference. At present, the standard neutral oil method of the American Oil Chemists' Society appears to be the best available method to use as a standard reference. Essentially, the oils are stripped of their polar compounds by passing them through a column of activated alumina. The reproducibility of the neutral oil method was not good but was improved by using alumina columns deactivated with water to facilitate removal of polar compounds and phospholipids.

2. Re-evaluation and Improvement of Official Cottonseed Standards for Reflecting More Accurately the Value of Products Obtained from Cottonseed. During the past season, the new pneumatic cottonseed sampler with modifications was used for the first time. The method, now official, was used by one-fourth of all seed processors. More mills are installing samplers at this time.

A continued study of price relationships of cottonseed and cottonseed products indicate that the oil, meal, and linters factors now in use were satisfactory for reflecting the value of seed at product prices prevalent during the past year.

3. Effect of Storage on Molds and Aflatoxins in Cottonseed. Bolls of cotton were selected from plants in six fields of cotton, four of which were heavily contaminated with boll rot and two which were free. Aflatoxins were found in the seed from the bottom part of the plants in one contaminated field and in the bottom, middle, and top of plants in another field. Cottonseed from all six fields, after ginning, did not indicate the presence of aflatoxins. The ginned seed from these fields, after normal storage at oil mills for 30 and 60 days, did not indicate the presence of aflatoxins.

A survey was made of the presence of aflatoxins in the cottonseed being processed and the meal produced at 52 oil mills which were located in all cotton production areas. Weekly samples were obtained beginning the third week of December. Approximately one thousand cottonseed and an equal number of meal samples were assayed for aflatoxin content. There appeared to be no correlation between free fatty acids content of the oil in the seed with aflatoxins in seed or meal.

Intact seeds, hulls, and meats from cottonseeds selected from fields heavily contaminated with boll rot showed large amounts of Aspergillus niger and only a small amount of A. flavus. It was also found that the hulls were superficially infected with large amounts of A. niger and A. flavus but A. niger was apparently more deeply entrenched or was more resistant to the NaClO_2 pretreatment. The meats were heavily infected with A. flavus, some of it evidently rather firmly established. However, not much A. niger showed up.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurements and Evaluation of Quality

Mullikin, Robert A., and Franklin E. Newton. 1964. Effects of Cotton Fiber Length and Length Distribution on Combing. Textile Industries, Vol. 128, No. 9, pp. 131-133, September.

Graham, John. 1964. Now--A Practical Way to Measure Drafting Force. Textile World, Vol. 114, No. 10, 60-62, October.

Shanklin, Edward H. 1964. Spindle Speed--Does It Affect Yarn Quality? Textile World, Vol. 114, No. 11, 70-71, November.

Carpenter, Frances. 1964. Array Vs. Fibrograph--Some Comparisons of Cotton-Fiber Length as Evaluated by the Suter-Webb Array and Digital Fibrograph Methods, in Relation to Spinning End Breakage and Yarn Strength. Textile Industries, Vol. 128, No. 12, 51-54, 64, December.

Garner, Warren E., and Robert A. Mullikin. 1964. Effects of Certain Drying Treatments in Ginning on Fiber Properties and Spinning Performance of Southeastern Cotton, Crop of 1960. PRR No. 85 - USDA,ARS, December.

LaFerney, Preston E., Robert A. Mullikin, and Walter E. Chapman. 1965. Effects of Defoliation, Harvesting, and Ginning Practices on Micronaire Reading, Fiber Properties, Manufacturing Performance, and Product Quality of El Paso Area Cotton, Season 1960-61. MRR No. 690 - USDA, ERS, ARS, January.

Parker, R. E., Edward H. Shanklin, and Scott C. Shaw. 1965. Hexadecyl Alcohol as a Spindle Moistening Agent for Mechanical Cotton Pickers. ARS-42-110-USDA, March.

Carpenter, Frances. 1965. Determining the Quality of Comber Noils with Fibrosampler Digital Fibrograph Combination. Textile Industries, Vol. 129, No. 4, 135-136, April.

Newton, Franklin E., Preston E. LaFerney, and Samuel T. Burley, Jr. 1965. The Effect of Trash on Cotton Processing Performance and Product Quality. Textile Bulletin, 32-39, May.

Chapman, W. E., and V. L. Stedronsky. 1965. Comparative Performance of Saw and Roller Gins on Acala and Pima Cottons. U. S. Dept. of Agric., MRR No. 695. June.

Webb, Robert W. 1965. Interrelationships Among Five Cotton-Quality Factors, Including Fiber Strength 1/8-Inch Vs. 0 Gauge, as Related to Yarn Strength at Three Staple-Length Levels. U. S. Dept. of Agric., MRR No. 684, May.

MARKETING FACILITIES, EQUIPMENT AND METHODS

Transportation and Facilities Research Division, ARS

Problem. Differences in varieties of cotton and in the environments of producing areas where it is conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to the efficient and economical handling, conditioning, and storing of these crops and to maintaining their quality. There is a need for improved designs for facilities based on functional and structural requirements, which will expedite the movement of cotton into, within, and out of the facility. There is also a need for handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving engineers engaged in both applied and basic research on, as well as application of known principles to, the solution of problems of handling, storing, and conditioning field crops in marketing channels. Research on the handling of cotton bales and humidification of storage compartments is conducted in cooperation with Calcot, Ltd., Bakersfield, Calif., at selected warehouses in California and Arizona. Research on aeration and storage of cottonseed is conducted at Stoneville, Miss., in cooperation with the Mississippi Agricultural Experiment Station and at commercial facilities in Mississippi; and is supplemented by a research cooperative agreement with the Mississippi Station.

The Federal effort devoted to research on cotton and cottonseed during the fiscal year 1965 totaled 2.5 professional man-years. Of this number 1.3 were employed in research on handling of bales of cotton and to the humidification of cotton storage compartments; and 1.2 to the aeration and storage of cottonseed.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Inter-agency Cooperative Programs

The Director of the Cotton Division, C&MS, requested the Division's Marketing Facilities Development Branch to study the work methods and layouts for 31 classing stations located in 15 States. This study is to develop possible ways to reduce the cost of handling the samples from the 13.5 million bales classed annually. These stations employ several thousand people during the classing season to grade about \$2 billion worth of cotton. Preliminary data has been collected on the present work methods and layouts in representative cotton classing stations in Tennessee, Missouri, Arkansas, and Texas. Recommendations for improved layouts and work methods will be presented to the Cotton Division after final data are collected and analyzed during the current cotton classing season.

B. Aeration and Storage of Cottonseed

At Stoneville, Miss., aeration studies were continued in selected commercial storages during the 1964-65 storage season with both improved and existing systems. For the second season, an improved experimental system cooled stored cottonseed to an average of 46° F. with 75 percent of the fan operating time required to cool a similar amount of cottonseed to 55° F. with the existing system. There was no reduction in seed viability during storage and the decrease in seed moisture averaged only 0.6 percent. Again, the use of more efficient fans and well designed duct systems was responsible for the improved performance efficiency.

A second improved system was designed and installed in a storage of a cooperator. A 7½-horsepower motor and industrial exhaustor-type fan used in this experimental system was more effective in cooling some 400 tons of stored cottonseed than a 75-horsepower motor and fan being used on an existing aeration system to cool an equal amount of seed.

Studies were initiated in a 14,000-ton oil mill storage where cottonseed depths vary from 12 to 75 feet. Some improvement in air delivery had already been achieved by using the central tunnel, instead of floor pallets, as the main aeration duct. However, the air velocity through the cottonseed near the main duct was estimated to be 50 feet per minute, still well above recommended velocities. Further improvements will be studied in 1965-66.

Laboratory studies were continued to obtain additional data on the effects of different duct surface areas and materials, and of compaction of stored cottonseed, on static pressure losses when moving air through the seed. Four types of duct sections and surface materials, each with two different surface areas, were tested. Preliminary analyses of test data indicate that when, at a simulated seed depth of 20 feet, the air velocity through the seed near the duct surface is increased from 10 to 20 feet per minute, the static pressure is nearly doubled. With the air velocity increased to 50 feet per minute, the observed static pressure was more than seven times as great as that observed at a velocity of 10 feet per minute.

C. Handling Cotton Bales and Humidifying Storage Compartments

1. Humidifying Storage Compartments. At Bakersfield, Calif., studies were continued on humidifying storage compartments to maintain the moisture content of stored bales of cotton at a desired level. Bales stored for one year under humidification showed that moisture content of cotton could be closely controlled and that humidification did not affect the commercial grade of the cotton. A series of tests were started in November 1965, in cooperation with the Market Quality Research Division and the Economic Research Service, using cotton of known history. The initial moisture

content of the bales compressed to flat, gin standard, and compress standard densities, ranged from 4.9 to 5.7 percent. During the winter and early spring months, moisture content of the bales stored under humidification was nearly the same ($6\frac{1}{2}$ percent) as that for bales stored normally without humidification. During the late spring and summer months, however, bales under humidification gradually increased in moisture content at the rate of 1 percent in 30 to 50 days, while bales not humidified gradually declined in moisture content. By July 30, humidified bales were being maintained at about 8 percent moisture content in the controlled environment room and at about 6 percent in the standard compartment. Bales stored with no humidification had a moisture content of about 4 percent.

2. Handling Cotton Bales. At Bakersfield, Calif., an improved layout was developed for the area in the compress room used for band splicing and other related operations. This layout provides for (1) storing the renovated bands in portable band carriers near the compress thus eliminating the operations of unloading and stacking the bands and then reloading them, (2) reducing the transport distance for moving bands by nearly 50 percent and (3) reducing crew sizes by some 50 percent. A draft of a proposed published report is being prepared.

An improved layout for loading compressed bales on road trucks was developed which provides for loading the trucks closer to the compress and the shipping segregating compartment than is practical with most conventional layouts. With this layout clamp trucks need not travel over 60 feet between the shipping blocks and the road trucks during loading operations; thus fewer clamp trucks and operators would be required.

Limited observations on the use of conveyors for moving bales from the dinky press to the main compress indicate that, although such use may permit some reduction in crew size, there would be insufficient increase in production rates to justify the installation of a conveyor system.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Aeration and Storage of Cottonseed

- Smith, L. L. 1964. Better Aeration of Stored Cottonseed. Agricultural Marketing, Vol. 9, No. 11, November 1964.
- Smith, L. L. 1965. Cottonseed Storage and Aeration in Commercial Facilities. Mississippi Agricultural Experiment Station. 78th Annual Report for year ending June 1965.

Smith, L. L. 1965. Aeration Studies of Commercially Stored Cottonseed. Proceedings of Association of Southern Agricultural Workers, Inc., February 1-3, 1965.

Smith, L. L. 1965. Aeration Studies of Commercially Stored Planting Cottonseed. Proceedings of 1965 Seedman's Short Course, Seed Technology Laboratory, Mississippi State University, May 3-6, 1965.

Handling Cotton Bales and Humidifying Cotton Warehouses

Bolt, C. D. 1964. Transporting Bales of Cotton with Large Clamp Trucks. ARS 52-1, 15 pp.

Bolt, C. D. 1964. Moving Cotton Bales Faster and Cheaper. Agricultural Marketing, Vol. 9, No. 12, December 1964.

COOPERATIVE MARKETING
Marketing Division, FCS

Problem. Farmers continue to increase their use of cooperative marketing.

These cooperative operations are conducted in a marketplace where handling and processing, transportation, and distribution technology is changing rapidly, and market organization and practices are undergoing major changes. Farms themselves have changed. Farmers and their cooperatives need research results that relate to these developments and new conditions to assist them in marketing efficiently. Such research will assist farmers to strengthen their bargaining power, increase marketing efficiency, and meet effectively the quality, quantity, and service needs of today's food and fiber marketplace.

Cooperative marketing is a direct and major way for farmers to get maximum returns from their products. Farmers own and operate cooperatives specifically to increase their income from crops and livestock. Gains are not automatic, however. Cooperatives must plan and actually conduct the specific marketing program and services that will yield best returns for their members. Marketing cooperatives must know what the consumer demands, as reflected in the market. They must be able to estimate the cost of serving the market in different ways. They must understand the possibility of major economies in a well-managed joint sales program, and understand the methods and potentials of bargaining. Management must achieve minimum costs through appropriate organization, good use of existing plant and personnel, and the correct selection and use of new equipment and methods.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation, and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D. C. Many of the studies, however, are done in cooperation with various State experiment stations, extension services, and departments of agriculture.

Federal professional man-years devoted to research in this area totaled 19.6, of which 2.3 man-years are devoted to cotton.

PROGRAM OF STATE EXPERIMENT STATIONS

Most of the commodity marketing research of the agricultural experiment stations is helpful to marketing cooperatives. Some projects, however, deal specifically with cooperative marketing problems, opportunities, and impacts. At the present time 10 States have 12 research projects in cooperative marketing.

Some projects evaluate the performance and organizational features of cooperatives. Different methods of pooling and their problems are studied so as to develop helpful principles. In the analysis of cooperative operations and in working with directors and managers, efforts are made to identify and solve the many problems that are arising. Particular attention is given to what services or functions should be provided by cooperatives. There is interest in learning more about the attitude of members and nonmembers toward cooperative marketing, especially the differences in these attitudes.

In the last few years more attention is being given to the role of cooperatives in achieving bargaining power for farmers. In connection with market structure studies, special attention is being given to the impact of cooperatives on market conduct and performance.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

Improving operating and handling methods

Research continued underway comparing costs of ginning by (1) conventional, (2) basket storage, and (3) central ginning methods. Findings indicate potential savings of about \$5 a bale for central ginning over conventional gins under appropriate conditions. Basket storage systems offer a reduction of a few cents to over \$1.50 a bale as compared to conventional ginning (on 6,000 bale volumes), particularly if the basket system includes an unloading system with medium to high capacity. Basket storage systems have substantially lower costs than second gins with low or inadequate volumes.

The cost of electric power at cottonseed oil mills under different electric rate schedules was analyzed. Different rate schedules result in widely different total cost, it was shown. Managers may use these findings to obtain more equitable power rates in some cases.

Analysis of operating costs of cooperative cottonseed and soybean processors continued. Findings help operators to locate inefficient features of their operations and on the basis of this information, act to reduce costs, and thereby increase returns to growers. Based on the work and experience with these processors, we continue to handle requests from interested groups on the feasibility of constructing and operating soybean processing plants. These reports also are used by other agencies in the Department of Agriculture and by the banks for cooperatives serving these mills.

Improving the organization, financing, and management of marketing cooperatives

A study was completed of operations and the organization of cotton and cottonseed cooperatives in the Lubbock area of Texas. Findings showed these cooperatives were successful because (1) there was an economic need, (2) there was good cooperation among members and management of the different types of cotton cooperatives, and (3) the objective of serving members was adhered to through the years.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

- Bradford, H. W. 1965. Cotton Cooperatives Responsive to Needs. News for Farmer Cooperatives (Jan.)
- Campbell, J. D. 1965. Developments and Opportunities in Cotton Cooperatives. American Cooperation 1965. Proceedings of the American Institute of Cooperation.
- Campbell, J. D. 1965. Costs of Using Cotton Basket Storage Systems, California and Texas, 1964. Marketing Research Report.
- Perdue, E. J. 1965. Economics of Delinting Cottonseed to Low Residual Linters at Oil Mills. Marketing Research Report No. 720.
- Perdue, E. J. and McVey, D. H. 1964. Canadians Host Co-op Oil Mill Conference. News for Farmer Cooperatives (Oct.)

ORGANIZATION AND PERFORMANCE OF MARKETS

Marketing Economics Division, ERS

Problem: The organization, services, and performance of the marketing systems for agricultural commodities are undergoing pronounced changes which are important to producers, marketing agencies, and consumers. The rapidity, complexity, and magnitude of these changes have resulted in some serious marketing problems which are further complicated by certain Government programs. The causes, results, and implications of these changes need to be better defined and evaluated to provide a more adequate basis for increasing the efficiency of the marketing systems and making them more responsive to public needs. Specifically, increased research emphasis is needed on changes in the structure and practices of the fibers marketing industries and their effect on marketing cost, efficiency, and product quality. In addition, increased emphasis should be placed upon defining the important quality characteristics of the various fibers and in relating this information to differences in value or price. Such an accelerated program would provide more complete and current information not only to producers and marketing agencies but also to officials responsible for public programs affecting agriculture and to teachers and extension workers.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of economic research in fibers marketing which reaches from the farmer to the consumer. Much of the research is problem solving in nature and is conducted by economists or personnel with both economic and technical training. However, an increasing proportion of our resources are being devoted to analysis broader in scope and particularly those types of analysis helpful to the Department and the public in evaluating alternative farm programs and the relative importance of various marketing segments. In nearly all studies, close cooperation is maintained with industry and trade groups and with private firms that generously provide essential data and make plant facilities available for observation. Last year, 10.4 professional man-years were devoted to cotton in this area of research.

PROGRAM OF THE STATE EXPERIMENT STATIONS

A recently activated regional project in the South is investigating the consumption patterns for cotton and competing fibers and decision-making agencies within the organizational structure of the cotton industry which influences cotton utilization. This research is to determine the relative importance of factors which influence the selection of fibers for given end products. States in the Southwest are cooperating on a regional study to determine the characteristics of cotton, type of ginning, and methods of

marketing that may have a significant influence on prices received by cotton producers. Variations in cotton prices are being related to grade, staple, uniformity, size of lot, variety, location, time of season, density, type of ginning, type of harvesting, and type of buyer. Other research is evaluating cotton grading and fiber testing instruments as a means in identifying cotton quality and improving market efficiency and prices. Another study is designed to determine the effect of moisture on the grade, staple, fiber properties, and the spinning performance of cotton lint. Additional work is investigating the problems and costs involved in alternative methods of packaging cotton; determining the effects of different ginning practices on ginning costs and the value of cotton lint produced, and, investigating the economic performance of cotton lint in the marketing system when harvested by mechanical spindle pickers as compared to mechanical strippers. This research involves 5.3 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Information on marketing costs and spreads for cotton, manmade fibers, and textile products is needed as a basis for appraising the competitive position of U.S. cotton, and to indicate possibilities for increasing market efficiency. An analysis of changes in the marketing system for cotton and cotton textile products indicates that markets for U.S. cotton continue to be adversely affected by strong competition from manmade fibers. However, technological developments, changes in market structure, and adoption of improved marketing practices have resulted in lower charges for some marketing services. For example, charges for saw ginning and wrapping a 500-pound gross weight bale of upland cotton in the United States averaged \$16.78 for the 1964-65 season, a slight decline from the previous season. Charges made by public cotton warehouses averaged 74 cents per bale for receiving and 52 cents per bale per month for insured storage in 1964-65, about the same as in the previous season. Although some charges declined, the spread between average retail costs of cotton products and the average farm value of lint used in their manufacture was \$1.87 in 1964, only 1 cent less than the record spread in 1961. The average retail price for cotton products was \$2.18 in 1964, 1 cent below the all-time high in 1961. The 1964 farm value of lint cotton used for making these products averaged 31 cents, 1 and 2 cents below comparable averages for 1963 and 1962, respectively. The farmer's share of the consumer's cotton dollar averaged 14 percent in 1964, compared to 15 percent in the two preceding seasons and to the high of 18 percent in 1951 and 1952.

Increasing volumes of roughly harvested seed cotton have necessitated larger investments in gin cleaning equipment in all areas of the Cotton Belt. The resulting increases in fixed costs along with rising costs for power and labor have tended to increase ginning costs. Several phases of research were completed this past year which provide ginners additional information on feasible means for increasing their efficiency. This research shows

that ginnerers in the West and Southwest could save 11 cents a bale in power costs by improving the power factor level in their plants. More efficient use of labor could reduce the cost of some ginnerers by as much as 2 to 5 percent. Prospects for decreasing costs by storing seed cotton at gins, and hence increasing seasonal volume, appear limited because of the added investments and increased needs for power and labor. Research on power requirements and costs for high capacity gins, specification for model gins and ginning organizations, and on improved means for reclaiming gin loss cotton are nearing completion.

Rising costs at cotton warehouses and large stocks of Government-owned cotton emphasize the importance for information on cost of receiving, storing, compressing, and outhandling of cotton at public warehouses. Administrative reports requested by the Agricultural Stabilization and Conservation Service on costs of nonstorage services have been completed for warehouses in the Delta and Texas High Plains producing regions, and for Texas port warehouses.

It is becoming increasingly evident that grade and staple length do not provide a satisfactory basis for selecting, processing, and pricing cotton. Deficiencies in pricing cotton are adversely affecting its quality and competitive position in the textile industry. Research results substantiate the desires of the cotton trade and the feasibility for establishing useful price differentials for fiber fineness and possibly for other fiber properties. Official price quotations, based on grade and staple length, in most of the designated spot markets frequently differ from prices actually paid for individual lots at a particular time. This indicates that for some sales the trade is pricing cotton on the basis of other quality characteristics than grade and staple length. For more effective pricing, greater attention must be given to length, length uniformity, strength, and other properties affecting the manufacturing performance of raw cotton, and the end-use value of manufactured products. Defoliation and excessive gin drying have been found to be particularly detrimental to some of these fiber properties.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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- Cooper, M. R., and Harris, W. F., March 1965. Recent Developments in Testing and Pricing Cotton for Fineness and Strength. MRR-699, 33 pp.
- Howell, L. D., November 1964. The American Textile Industry--Competition, Structure, Facilities, Costs. AER-58, 146 pp.
- LaFerney, P. E., Mullikin, R. A., and Chapman, W. E., January 1965. Effects of Defoliation, Harvesting, and Ginning Practices on Micronaire Reading, Fiber Properties Manufacturing Performance, and Product Quality of El Paso Area Cotton, Season 1960-61. MRR-690, 33 pp.

- Looney, Z. M., Wilmot, C. A., Holder, S. H., and Cable, C. C., May 1965. Cost of Storing Seed Cotton. MRR-712, 23 pp.
- Ponder, H. G., May 1965. Charges for Ginning Cotton, Costs of Selected Services Incident to Marketing, and Related Information, Season 1964-65. ERS-2, 2 pp.
- Potter, Joseph R., Jr., April 1965. The Traffic Pattern of American Raw Cotton Shipments, Season 1961-62. MRR-705, 35 pp.
- Pritchard, D. L., October 1964. Spot Cotton Quotations: Their Relation to Spot Values and to Average Differentials. MRR-677, 38 pp.
- Wilmot, C. A., and Alberson, D. M., November 1964. Effects of Oversized Motors on Power Costs in Ginning Cotton. ERS-203, 28 pp.

DEVELOPMENT OF MARKETS
Marketing Economics Division, ERS

Problem: Of increasing economic concern is the problem of how to improve and strengthen markets for farm products in face of a continuing rise in production, higher distribution costs, and competition from non-agricultural products. The problem of increasing demand for farm products to meet rising productivity has become progressively more pronounced in the last decade. Interest in the development of markets has mounted as larger and larger financial outlays become necessary for price-support operation and maintenance of reasonable levels of farm income.

Also, the problem of developing markets have involved the finding of new and improved uses for agricultural products that meet with consumer acceptance and/or industrial requirements.

Research in the development of markets is designed to determine how best to maximize the use of farm products, keeping in mind consumer desires and returns to producers. This involves economic studies of: The effectiveness of alternative promotion, merchandising, and advertising techniques; and market potential and commercial feasibility of new and improved products.

Through research on the different facets of market development, information is provided farm groups, processors, and distributors which enables them to make the most of new market outlets and opportunities. In addition, they are better able to assess the demand of consumers from the standpoint of kinds and forms of food and services deemed most satisfactory.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program of economic research on the development of markets. It consists of both basic and applied research on agricultural commodities which includes the development of general principles in advertising and promotion and evaluation of the commercial feasibility and market potential for new and improved products.

Much of the research on the development of markets is carried out in cooperation with producer groups, trade associations, and State Departments of Agriculture. Financial contributions to the research effort are often made by cooperating groups.

The Department's research program on the development of markets is centered in Washington, D. C., with a small number of field stations located throughout the States. The scientific effort devoted to the development of markets for cotton in the past year amounted to 0.5 professional man-years.

PROGRAM OF STATE EXPERIMENT STATIONS

A. Products and Services

Very little, if any, research in economics is carried out in the area of products and services by State agricultural experiment station personnel. Much research is being conducted on the development of improved products and uses, but it is in the area of technology.

B. Merchandizing and Promotion

Studies of consumer acceptance, preference and product evaluation in home use situations represent an ongoing phase of the State program. Current work deals with food and fiber items as well as nursery products. This research is undertaken to determine specific unknown wants of consumers and thus is closely allied with the product development phases of the station's program.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Products and Services

Emphasis is being placed in the current program on ways of maintaining agricultural products' shares of the market--particularly where declines in per-person consumption has occurred. In specific commodity areas, this requires a reliable means of identifying the salient consumer wants or needs and then providing researchers with the information so they can channel the research and development programs to maximize product success and consumer satisfaction. Research of this nature has been undertaken in several important commodity areas.

On the fiber side, the research approach also includes evaluation of the sales potential of new properties as putting stretch in cotton and eliminating shrink from wool. A study completed in the past year pointed out that machine launderability given to wool fabrics will enhance wool consumption in markets that consumed 131 million pounds of wool, a market now subject to substitution by easy-care synthetics. Similarly, research in the planning stage on cotton will explore the extent to which new cotton finishes and cotton products have expanded particular markets for cotton and how well these new developments are meeting new market requirements.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Hall, Richard, March 1965. The Changing Market for Cotton. Cotton Situation, 4 pp.

COMMODITY SITUATION AND OUTLOOK ANALYSIS
Economic and Statistical Analysis Division, ERS

Problem. Prices to producers are relatively unstable and conditions of agricultural production are changing rapidly. Thus, the farmer stands in special need of frequent accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. It has long been a goal of the Department to provide the farmer with economic facts and interpretations comparable to those available to business and industry. Such information is provided through a continuous flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting major farm commodities.

USDA AND COOPERATIVE PROGRAM

The program includes a continuous appraisal of the current and prospective economic situation of cotton. These appraisals, developments of interest to the industry, and results of special studies are published 4 to 6 times a year in the various commodity Situation reports, with brief resumes in the quarterly Demand and Price Situation, and when appropriate in monthly issues of the Farm Index and the Agricultural Outlook Digest. Comprehensive analyses of the current and prospective situation are presented at the Annual Outlook Conference, and more limited appraisals given at regional and State conferences and at meetings with industry groups. Special analyses are prepared from time to time on the probable effect of proposed programs on the supply, price, and utilization of the various commodities. Basic statistical series are developed, maintained, improved, and published for general use in statistical and economic analysis.

The total USDA commodity situation and outlook program currently involves 20.5 professional man years. Of this total effort 1.5 are devoted to cotton.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part the States depend on the U. S. Department of Agriculture for the yearly across-the-board commodity situation and outlook research. There is increasing interest in longer range price prediction because of the growing specialization of farms, which makes yearly enterprise shifts less common and less feasible, and which calls for large capital commitments over longer periods of time. The State extension staff members supplement and adapt such research information to meet the commodity situation of their States.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

Enactment of cotton legislation in early April 1964 improved the competitive price position of American upland cotton in the domestic market by reducing the net cost of raw cotton to users. As a result, the rate of cotton consumption increased sharply during the 1964-65 crop year. However, the increase in consumption was more than offset by a sharp decline in exports. At the same time, the 1964 crop was large because of record-high yields and carryover rose nearly 2 million bales during 1964-65. Prospects are for some further increase in carryover during the current marketing year.

Because of this continued buildup in the cotton carryover, a number of special analyses were prepared for the Secretary's office on the probable effect of alternative programs on price, supply, and consumption of cotton. Also, special analyses were made of factors affecting U. S. exports of cotton. Data and analyses were provided to the Secretary of Agriculture's Advisory Committee on Cotton. An annual supplement to a basic statistical handbook, including data for 1964-65, was published. Data were updated for publication of a statistical handbook for extra-long staple cotton. Conversion factors were derived to be used in estimates of the raw fiber content of cotton, wool, and man-made fiber fabrics used by the military.

Special analyses were completed on the impact of reduced cotton prices following new legislation on mill use of raw cotton and on imports and exports of cotton textiles. These included analyses of effects of price and other factors on the use of cotton and man-made fibers. On a relative price basis, cotton competes most directly with rayon staple fiber. The non-cellulosic fibers compete on the basis of qualitative factors, promotion and advertising, and to a lesser extent on the basis of price. The improved competitive price position of cotton in the domestic market, resulting from enactment of new legislation in 1964, slowed the rate of increase in use of rayon. Use of non-cellulosic fibers, however, continued to increase.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Donald, James R. Cotton Situation. Published 6 times a year. ERS, USDA, Washington, D. C.
Hall, R. March 1965. The changing market for cotton. Cotton Situation. pp. 11-14.
Statistics on Cotton and Related Data. October 1964. Supplement for 1964, Statistical Bulletin No. 329.

SUPPLY, DEMAND AND PRICE OF AGRICULTURAL COMMODITIES
Economic and Statistical Analysis Division, ERS

Problem. Producers, processors, distributors and consumers need more accurate quantitative knowledge of the interrelationships among prices, production, and consumption of farm products. Farmers and farm-related businesses need to know the prices they may expect from different levels of production to plan for maximum returns. Cooperatives, processors, and distributors need adequate statistical information on price and consumption responses under different supply conditions to aid in distribution of agricultural supplies that lead to maximum returns to farmers. Similarly, Congress and the administrators of farm programs need to evaluate alternative proposals to modify existing price support, production, marketing and other programs in terms of their impact on production, consumption and prices at both the farm and retail levels. The development of new statistical methods and the application of existing methods for measuring the interrelationships among prices, production, and consumption of farm products serve these needs by strengthening outlook and situation work, providing the basis for special analyses of alternative agricultural policies, and assisting research workers in agricultural economics.

USDA AND COOPERATIVE PROGRAM

The Program of basic research into the factors affecting prices, supply, and consumption of principal agricultural commodities is concerned with four broad areas: (1) Measurement of consumer response to price, income, and other factors; (2) measurement of producer response to price and other factors; (3) measurement of the effect of supply and demand factors on prices to farmers and to consumers; and (4) improvement of statistical techniques for measuring agricultural economic relationships and for the development of statistical formulas which can be used in making price, supply, and consumption forecasts and in appraising economic implications of alternative programs.

The current emphasis on cotton is to measure the economic factors that affect the price, supply, and utilization of cotton and cotton products.

A facet that is becoming increasingly important in carrying out the statistical and econometric work of the Division is the use of electronic computers. The program includes continual evaluation of latest developments in the field, equipment and computer programs available for use, and the application of this to our data submitted for machine processing.

The USDA program of research on cotton involves 1.5 professional man years and is located in Washington, D. C.

PROGRAM OF STATE EXPERIMENT STATIONS

Many of the States carry on supply, demand, and price analyses for the products of their State. Much of the research is commodity oriented, though some projects are of a highly mathematical and theoretical nature aimed at improving price analysis methodology.

The research on demand for a large number of commodities will indicate the price elasticity, the income elasticity, and the cross elasticities of the commodities being studied. Because researchers are finding that some changes cannot be explained by price, income, and supply of competing commodities there is increasing research interest in social and psychological factors affecting demand.

The supply response to price changes is a matter that is receiving considerable attention. This is in part because of its significance to farm incomes and government programs. Significant progress is being made in understanding the relationship of the capital structure on farms to supply response and thus to the difference between long-run and short-run supply responses.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

Research during the past year has been concentrated on the price and utilization of cotton and cotton textiles, with separate statistical analyses to isolate the important factors in both domestic and foreign outlets. A manuscript presenting results of the analysis of foreign outlets for U.S. cotton is nearing completion. Results of analyses indicates that the level of U.S. cotton prices in foreign markets has affected acreage devoted to cotton in foreign countries. This in turn has affected the level of foreign cotton production which competes with U.S. cotton in world markets. Following the end of World War II and into the mid-1950's, both acreage and production in foreign countries tended upward in response to relatively high prices for cotton. Lower prices in world markets since the mid-1950's have slowed the acreage expansion. However, production continued to increase because of rising yields per acre.

U.S. exports of cotton are also related to the level of cotton consumption in foreign countries. Analyses indicate that cotton consumption abroad is affected by the level of world cotton prices, prices for and consumption of synthetic fibers, population, and changes in the level of economic activity. Year-to-year change in cotton stocks in foreign countries is also reflected in the volume of U.S. cotton exported. Equations have been developed for forecasting foreign acreage, production and consumption of cotton.

Exploratory analyses have been made of the role of price and other factors in consumption of cotton for apparel, household, and industrial uses to gain insight into the domestic utilization of cotton. Analyses are also

underway to determine the role of price and other factors in the use of fibers in fabrics for the military. The emphasis is on competition between cotton and synthetic fibers for these uses.

An article was published which analyzed the effect of prices and other factors on the use of cotton and synthetic staple fibers. On a relative price basis, cotton competes most directly with rayon staple fiber. With more competitive prices for cotton during the past year, the rate of cotton use increased sharply, while the rate of increase in rayon staple fiber was slowed.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Wittmann, Charles H. and Donald, James R. November 1964. Seasonal Adjustments, Cyclical Movements, and Trends in Consumption of Cotton and Man-made Staple Fibers. Cotton Situation, pp. 14-24.

CONSUMER PREFERENCE AND QUALITY DISCRIMINATION--
HOUSEHOLD AND INDUSTRIAL
Standards and Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for consumers to express to producers either pleasure or displeasure with available merchandise. To market agricultural products more effectively, it is necessary to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on consumers' attitudes toward old and new product forms of agricultural commodities, preferences, levels of information or misinformation, satisfactions or dislikes, and what product characteristics would better satisfy current consumers and/or attract new ones. It is also important to know the relationship between the consumption of one agricultural commodity and another in consumers' patterns of use, the relationship between agricultural and nonagricultural products, and probable trends in the consumption of farm products. Producer and industry groups as well as marketing agencies consider such information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increases returns to growers.

USDA AND COOPERATIVE PROGRAM

The Special Surveys Branch conducts applied research among representative samples of industrial, institutional, or household consumers and potential consumers. Such research may be conducted to determine preferences, opinions, buying practices, and use habits with respect to various agricultural commodities; the role of competitive products; acceptance of new or improved products; and consumers' ability to discriminate among selected attributes of a product or levels of an attribute, and the preferences associated with discriminable forms.

In addition to the studies of consumer preference and discrimination, the Branch also provides consultants and conducts special studies, upon request, for other agencies in the USDA or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The research is carried out in cooperation with other USDA or federal agencies, State experiment stations, departments of agriculture, and land-grant colleges, and agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff with the assistance of locally recruited personnel.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Fibers in wearing apparel. The rapid expansion in recent years in the use of manmade fibers and blends necessitates up-to-date evaluations of consumer reactions to natural fibers in specified end uses. Such data give industry a better understanding of its markets, and provide a guide for planning physical science research in industry and within the Department on product improvement as well as educational, promotional, and merchandising efforts designed to strengthen the market position of cotton and wool.

A preliminary report on the results of a contract study on reactions to fibers in selected items of clothing among a nationwide sample of teenage boys and girls was issued during the fall of 1964; a final report presenting more detailed findings is in preparation. Data from the study have been discussed in a previous progress report.

The exploratory phase of the nationwide contract study of women's opinions about fibers in apparel for warmer weather was completed. In the exploratory interviewing, groups of women were studied in depth to determine their attitudes and opinions with respect to certain items of clothing and the fibers in them. The findings guided the designing of two types of questionnaires for use among comparable samples of women. This will permit detailed evaluation of the advantages and disadvantages of the two methods. One of the questionnaires is composed mainly of structured questions; the other uses the traditional open-end questions to collect the attitudinal responses. The pretest for this study is scheduled for July; actual field work is planned for early fall of 1965.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Owings, Ann. September 1964. Young People's Use and Appraisal of Natural and Competing Fibers Used in Wearing Apparel--A Preliminary Report.
SRS-4. (S&R 3-1)

IMPROVEMENT OF CROP ESTIMATING PROCEDURES
Standards and Research Division, SRS

Problem. The Statistical Reporting Service produces a large number of current statistics pertaining to agriculture. Because of limited resources, statistical methods were devised with a view to producing the most information for the least cost. These methods are subjective in nature and are based largely upon self-selected samples from voluntary crop reporters who fill out and return mailed questionnaires. With the development of modern statistics, new methods based upon probability sampling have been developed. Although surveys based upon probability sampling are more expensive to conduct than the traditional self-selecting mailed survey, these new methods offer a means of increasing the precision and reliability of the estimates. Because of the need by the agricultural economy for high quality statistics, it is mandatory that the statistical theory and methods be developed and adapted to the collection of agricultural statistics. Some of the new procedures have already been introduced but there is an urgent need for a continuing research to devise efficient survey methods so as to make possible continuing improvement in the quality of SRS statistics.

USDA AND COOPERATIVE PROGRAM

The Department of Agriculture conducts a program of applied research designed to strengthen and improve the methodology used in collecting agricultural statistics. Work under this program is done in Washington, D. C., and in SRS field offices located in the States concerned.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Objective Measurement of Yields in Irrigated Cotton. This study was continued on a larger scale (310 sample fields) in 1964 to test previous results, and to obtain data for refining forecasting parameters and early season models. Based upon this study and the earlier studies, the following changes were made in the forecasting program for 1965:

- (1) Total samples assigned in the three Western States were increased from 320 to 480 in order to more nearly approximate the degree of precision desired at an operational level.
- (2) California was divided into two distinct areas of production--the Imperial Valley and the San Joaquin Valley area.
- (3) One early season forecasting model was altered in New Mexico and the San Joaquin Valley area of California.

Further refinement can be expected in the forecasting parameters as data are accumulated over years from the increased number of sample fields.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

None.



